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AE R-4231
June 17, 1977

RETURN BEAM VIDICON (RBV) PANCHROMATIC TWO-CAMERA SUBSYSTEM FOR LANDSAT-C

FINAL REPORT

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Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

Contract NAS 5-22350

Prepared by:

RCA Government Systems Division
Astro-Electronics, Princeton, N. J.

RCA | Government and Commercial Systems | Astro-Electronics Division
PO Box 800 | Princeton, New Jersey 08540 | Telephone (609) 448-3400

IN REPLY REFER TO: AE-458-FHB-0071-77

RCA

National Aeronautics and Space
Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Attention: Mr. R. Johnson, Code 430

Subject: NAS5-22350
FINAL REPORT

Gentlemen: June 23, 1977

In accordance with Article XVII of the subject report this letter makes distribution of the Final Report for the subject contract.

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F.H. Bartholomew
Contract Representative

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ABSTRACT

This final report summarizes the work performed to design, fabricate, and qualify a two-inch Return Beam Vidicon (RBV) panchromatic two camera Subsystem, together with Spare Components, for the Landsat-C Satellite; the basis for the design was the Landsat 1&2 RBV Camera System. The purpose of the RBV Subsystem is to acquire high resolution pictures of the Earth for a mapping application.

Where possible, residual Landsat 1 and 2 Equipment was utilized: The Vidicons used on the Cameras were selected from Landsat 1 and 2 inventory and were qualified; the Landsat 1 and 2 test equipment was modified for use with the new camera system; the design of the camera system was tailored to be compatible with the Landsat 1 and 2 Receiving Site Equipment; and the Spare Landsat 1 and 2 camera was converted into the Landsat C qualification Model.

This program included one major subcontract; lenses and collimators were designed, fabricated, and qualified by Contraves-Goerz Co. specifically for this application.

This work was performed under Contract NAS5-22350 by RCA Corp., Astro-Electronics, Princeton, N.J. for NASA, Goddard Space Flight Center, Greenbelt Maryland. The work commenced on May 1, 1975. The Flight Subsystem was delivered on January 31, 1977; thereafter, the Spare Components were delivered on March 31, 1977.

ACKNOWLEDGEMENTS

The RCA Program Manager for the RBV Landsat-C program, Mr. Bert Soltoff, was responsible for managing all phases of the RCA program. Mr. L. Wilson, the NASA/GSFC technical officer, provided technical review and cognizance for NASA throughout the program. The delivery of all hardware, as scheduled, in spite of a 3-month reduction in flight system delivery requested by NASA and agreed to by RCA at the onset of the program, could only have occured because of the close co-operation of all NASA personnel involved.

The RCA Astro-Electronics personnel who participated in writing this report are noted below with their contributing sections shown.

James D'Arcy	Introduction; Two-Camera Subsystem; Functional Performance; Status of Equipment, Recommendations; Guidelines
Robert G. Horner	Electrical Performance; Test and Receiving Site Equipment; Program Test Chronology
Edward Moshey	Mechanical Performance; Lens Procurement
Max Mesner	Vidicon Selection

In addition, technical material generated by the following RCA personnel was consulted during the writing of this report.

J. Armington
L. Freedman
M. Kravitz
R. Marsala
R. McCowan

ABBREVIATIONS

CCC	Camera Controller Combiner
CE	Camera Electronics
BTE	Bench Test Equipment
DQM	Design Qualification Model
EBR	Electron Beam Recorder
QLM	Quick Look Monitor
RBV	Return Beam Vidicon
RSE	Receiving Site Equipment
STE	Special Test Equipment
TPG	Test Pattern Generator
VIATS	Vidicon Imaging Assembly Test Set
VPASS	Video Processor and Sync Separator
VTR	Video Tape Recorder

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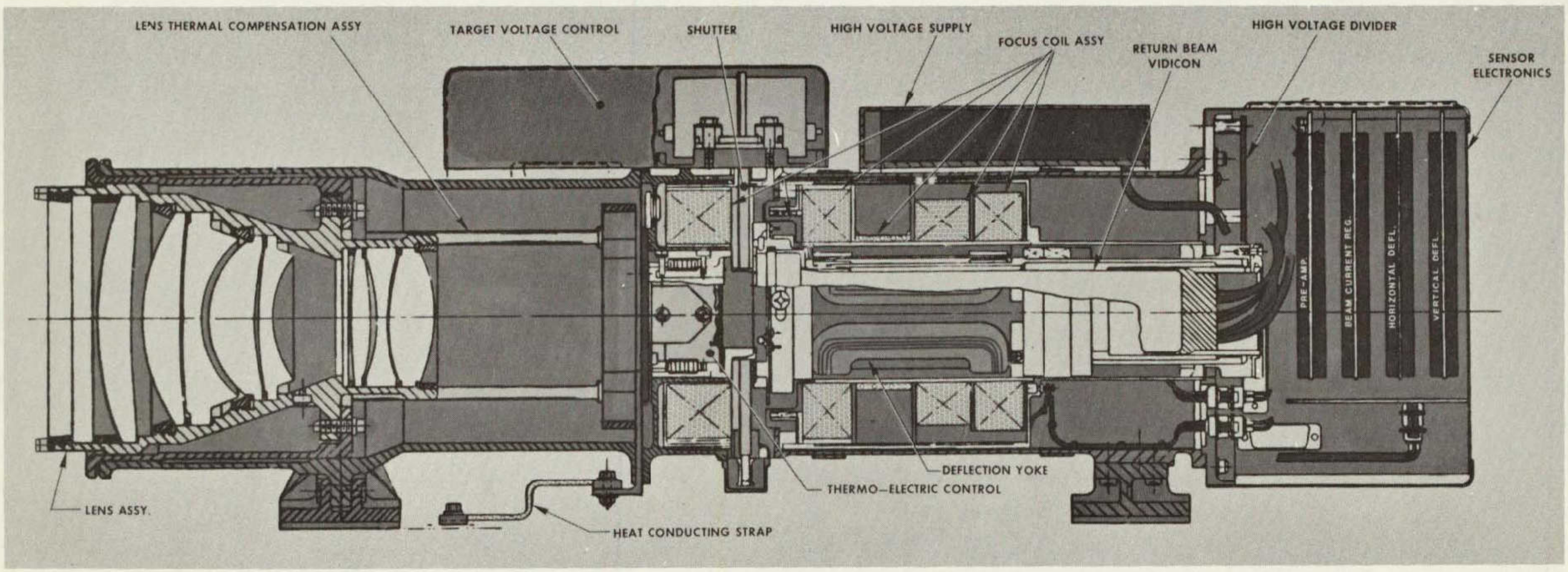

Frontispiece - Landsat-C Return Beam Vidicon Camera

SECTION I

INTRODUCTION

A. PURPOSE OF REPORT

This is the final report covering work performed by RCA, Astro-Electronics, Princeton, New Jersey, for NASA/GSFC, Greenbelt, Maryland on the Two-Inch Return Beam Vidicon (RBV) panchromatic two camera subsystem for Landsat-C (NAS5-22350) since May 1, 1975.

B. CONTRACT OBJECTIVES

The contract objectives were to design, fabricate and qualify a Two-Inch Return Beam Vidicon (RBV) panchromatic two camera subsystem, together with spare components, for the Landsat-C Satellite; the basis for the design was to be the Landsat 1&2* RBV Camera System.

The purpose of the RBV subsystem is to acquire high resolution optical images of the earth for a mapping application. There are two cameras in the system; each is a panchromatic (505 to 750 millimicrons) camera configured to view a nominal 53 nmi square area. Camera pointing angles are such that the two cameras view adjacent areas of the earth providing a nominal coverage of 98.5 by 53 nmi for each picture taking cycle. This cycle is repeated every 12.5 seconds in order to provide continuous coverage (with a small overlap) in the direction of flight. The optical images acquired by the cameras are

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*Prior to becoming operational, Landsat 1&2 were designated Landsat A&B; Landsat was originally known as ERTS (Earth Resources Technology Satellite).

sequentially processed (first camera 1 and then camera 2) into television video signals which are combined with other spacecraft data. The resulting signal is either transmitted to earth or recorded on video tape for later transmission.

Several uses have been planned for the television signals which are transmitted to earth. These signals will be used to produce high resolution (nominally 40 meters ground resolving power) photographs of the earth. These photographs will be used to locate control points (e.g. highway intersections, etc.) more accurately than on previous Landsat Missions (the Landsat-C RBV has higher resolving power than the Landsat 1&2 RBV). In addition, an experiment is being planned to demonstrate the feasibility of combining the higher resolution picture information of the Landsat-C/RBV with the quality color picture information of the Multi-Spectral-Scanner (MSS) in order to provide the "best of both worlds."

Although the RBV subsystem does provide television signals, it is unlike a commercial television camera; rather, it is a very precise scientific instrument. It was developed to utilize and preserve the extremely high resolution capabilities (at least 90 lp/mm) of the RCA Return Beam Vidicon. The cameras of this subsystem require manufacture and operational tolerances, in some cases, of less than ±0.0005 inches or less than 0.04%, over the predicted life of the mission. As an example, the electron-optics tolerances, both mechanical and electrical, must be tight enough to preserve the aforementioned 90 lp/mm resolution throughout the life of the program (center resolution, $10^{o}C$ to $30^{o}C$ operating temperature, 50/1 or better contrast ratio). In addition, there was a weight and power constraint imposed upon the system; the subsystem weighs about 165 lbs and requires an average power of about 136 watts.

This work was performed under Contract NAS5-22350 for NASA-GSFC, Greenbelt, Maryland by the Astro-Electronics facility of RCA; the overall program schedule is shown in Figure I-1. The primary objectives of this program were to:

- Modify the design of the Landsat 1&2 RBV System to meet the Landsat-C/RBV subsystem requirements;
- Incorporate the design modifications into the Landsat 1&2 Spare Components, convert it to the Landsat-C Design Qualification Model, and qualify it to prototype levels;
- Redesign and Modify the Test Equipment to be compatible with the camera changes;
- Select Vidicons from existing stock and qualify them;
- Procure newly designed lenses and collimators;
- Fabricate and qualify a two camera RBV flight system;
- Fabricate and qualify spare flight components; and identify Receiving Site Equipment Changes required to accommodate both the Landsat 1&2 RBV and the Landsat-C/RBV.

As a result of this effort, the following items were deliverd:

- A Design Qualification Model
- A Two Camera RBV Flight System
- A Set of Spare Flight Components; and
- Four New Collimators.

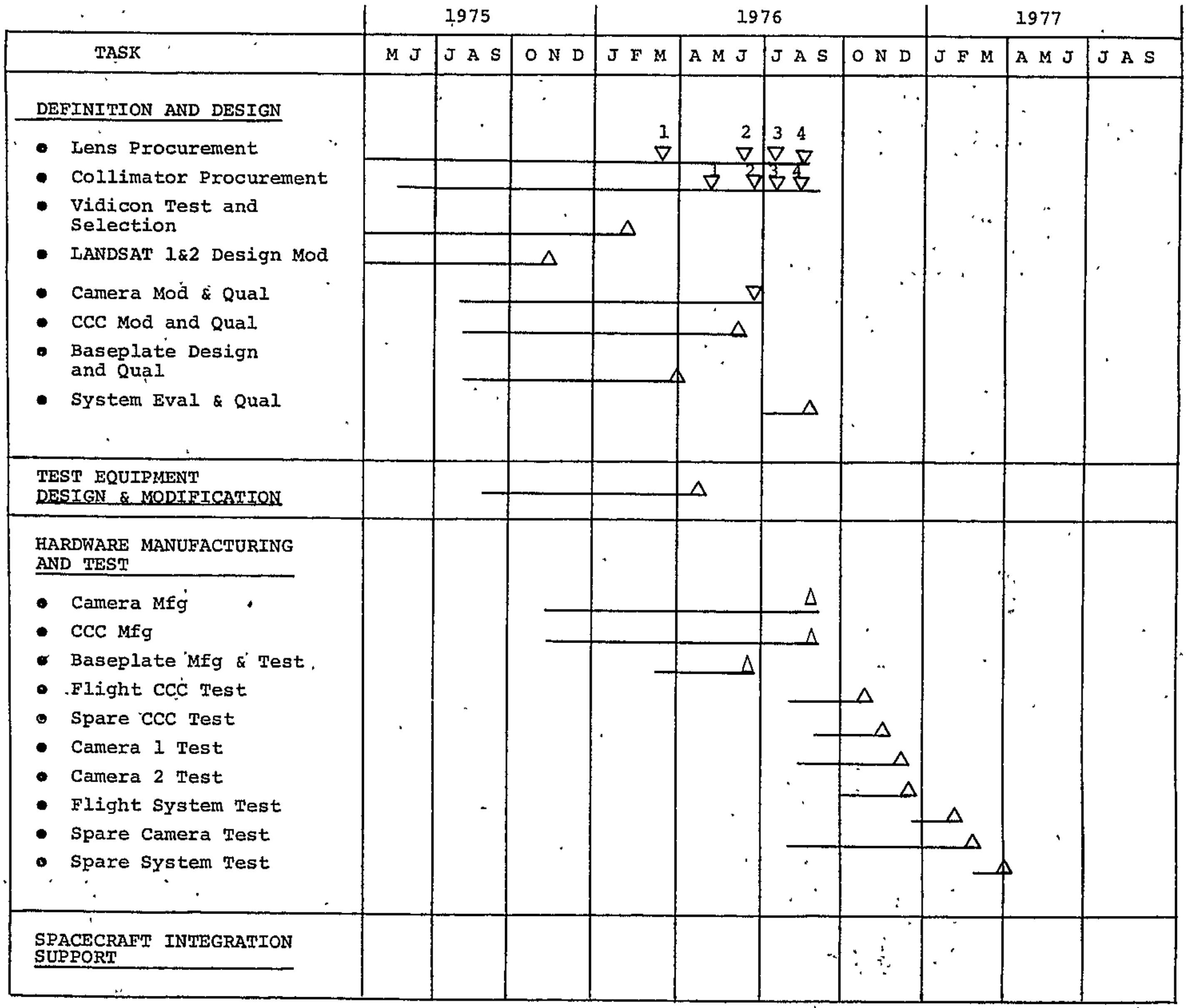

Figure I-1. Landsat-C/RBV Program

In addition, the following test equipment units were modified to be compatible with the new camera design:

- One Vidicon Imaging Assembly Test Set (VIATS);
- Two Special Test Equipments (STE); and
- Two Bench Test Equipments (BTE).

The modifications are discussed in Section III.

C. SYSTEM PERFORMANCE OBJECTIVES

The System Performance required by the GSFC specification (GSFC 490-C-290A) is defined in detail in RCA Performance Specification PS-2284900 and is summarized in Table I-1. In general, this performance has been met except for some small deviations, such as shading, for which waivers were granted.

D. SUMMARY

The Landsat-C/RBV program was begun on May 1, 1975. The primary purpose of this program was to provide a Flight model of the Return Beam Vidicon (RBV) panchromatic two camera subsystem for the Landsat-C satellite; the basis for the design of this camera system was the Landsat 1&2 RBV camera system. During the course of this program, a Qualification model, a Flight model, and spare components were fabricated tested, and qualified.

TABLE I-1. MAJOR PARAMETERS AND SYSTEM PERFORMANCE REQUIREMENTS OF THE RBV TWO-CAMERA SUBSYSTEM

Parameter	Performance Requirements	Remarks
Imaging Tube	Two-Inch Return-Beam Vidicon (RBV) with ASOS* Photoconductor	
Deflection and Focus	Electromagnetic	
Image Size on Target	1 inch x 1 inch	
Exposure Time	2.4, 4.0, 5.6, 8.0, and 12.0 milliseconds	5.6 ms nominal
Lens Effective Focal Length	236 millimeters nominal	
Lens Relative Aperture	f/2.9	
Horiz Limiting Resolution (Center)	4500 TV Lines (90 lp/mm)	Tables IV-3, 12, 18
Edge Resolution	80% of Center Resolution	
Dynamic Range	30 to 1	
Highlight Radiance	2.013 mw/cm^2 - SR (505 to 750 mμ)	
Shading	$\leq$15% within 1 inch diameter circle; $\leq$25% elsewhere	Tables IV-2, 15, 20
Residual Image	Less than 3%	
Image Distortion	$\leq$1%	Tables IV-6, 14, 21
Video Bandwidth	3.2 MHz	
Aspect Ratio	1:1 at Set-up	Tables IV-6, 14, 21
Skew	$\leq \pm 0.5°$	Tables IV-6, 14, 21
Size and Centering	$\leq \pm 2\%$	Tables IV-6, 14, 21
Two Camera Cycle Rate	12.5 seconds between pictures (see Figure II-1 for breakdown)	

* Antimony sulfide oxy-sulfide.

TABLE I-1. MAJOR PARAMETERS AND SYSTEM PERFORMANCE OBJECTIVES OF THE RBV TWO-CAMERA SUBSYSTEM (Continued)

Parameter	Performance Objectives	Remarks
Power Consumption	142 watts average; 150 watts peak	**
Power Supply	-24.5V ±2%; -28V unregulated	
Read Horizontal Rate	1,250 lines/sec	
Active Horizontal Lines	4,125	
Readout Frame Time	3.5 Seconds (3.3 Seconds, Active)	
Peak Signal/rms Noise	33 dB	Tables IV-5, 16, 22
Readout Position	Camera 2 follows Camera 1	
Ground Coverage (From 492 nmi orbit)	98.5 x 53 nmi/cycle	
Spectral Band	505 mμ to 750 mμ	
Weight	170 pounds	Actual is 162.34 pounds
Operating Environment	492 nmi earth orbit vacuum and 10°C to 30°C temperature range.	

** Actual power is 136 watts average; 142.5 watts peak.

The Qualification model consists of a new prototype baseplate and the spare Landsat 1&2 components (Sensor, Camera Electronics, and Camera Controller Combiner) which were updated to meet the Landsat-C requirements. Following the design modification phase, updating of the Landsat 1&2 components was begun in March 1976. Subsequent evaluation, test and qualification, including prototype vibration[1] and thermal vacuum exposure, was successfully completed in August 1976.

The Flight model includes: a sensor/baseplate assembly comprised of two sensors and a baseplate; two camera electronics packages (one for each sensor) and a Camera Controller Combiner (CCC). Assembly and test of the Flight model components was begun in August 1976. After each camera (consisting of a sensor and a camera electronics) and the CCC had been assembled and evaluated, they were then integrated to form the two-camera Flight model. Integration test and qualification (including vibration and thermal vacuum) of the Flight model was successfully completed on January 31, 1977, the date specified by the contract. Thereafter, it was delivered to the spacecraft contractor and has since been integrated into the Landsat-C spacecraft.

The spare components include a single camera (comprised of a sensor and its camera electronics), and a CCC. Integration, test, and qualification (using the prototype baseplate and a dummy sensor) was successfully completed on March 31, 1977, the date specified by the contract. These components are to remain at RCA until after the launch of Landsat-C, so that periodic testing may be more readily accomplished.

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1. Since the Qualification Model included only one sensor a dummy sensor was placed in the second sensor position during vibration.

To comply with the Landsat-C/RBV specifications, it was necessary to design and qualify a lens specifically for this application. In addition, a specially designed collimator was required to match the particular characteristics of the lens. Four lenses and four collimators were procured from Contraves-Goerz Co.

The vidicons installed in the cameras were obtained from the LANDSAT 1&2 residual store. Since 13 of these vidicons had been designated Landsat-C candidates, it was necessary to conduct a test program (including spectral response measurement) in order to select the required four vidicons, three for the new cameras and one spare. The vidicon selection was made in January 1976.

To test the cameras, it was necessary to modify several items of Landsat 1&2 ground equipment in order to be compatible with the Landsat-C cameras. The equipment modified includes:

a) One Vidicon Imaging Assembly Test Set (VIATS) for setting up and evaluating the integrated imaging assembly (focus coils, deflection yoke, vidicon etc.);

b) Two sets of Special Test Equipment (STE) for setting up and testing single cameras; and

c) Two sets of Bench Test Equipment (BTE) for testing and evaluating the two-camera subsystem.

The other Landsat 1&2 units, including the computer and the Quick Look Monitor, were used without modification.

In addition, recommendations were made for modifying the Receiving Site Equipment (RSE).

Currently, the Flight Model has been integrated into the Landsat-C spacecraft. It is now being tested as part of the spacecraft; RCA is providing field support as required. Recommendations have been made to activate these cameras at least every three months in order to ensure against nominal performance degradation.

SECTION II

TWO CAMERA SUBSYSTEM

A. GENERAL

The Two Camera RBV Subsystem of the Landsat-C Spacecraft is used to produce high resolution television pictures of the Earth for a mapping application. Each of the two cameras is configured to take panchromatic (505 to 750 millimicrons) photographs of a nominal 53 nmi square area. Camera pointing angles are such that the two cameras produce adjacent views, thus providing a nominal 98.5 by 53 nmi picture swath along the spacecraft track of each picture taking cycle. As indicated in Figure II-1, the picture taking cycle is repeated every 12.5 seconds thus producing a small overlap in the direction of flight for a 492 nautical-mile orbit. The camera video cycles are processed sequentially (first camera 1 and then camera 2) and mixed with time-code and station-keeping data; this information is then transmitted to a ground station (when the spacecraft is within range) or recorded on video tape for later transmission.

As shown in the block diagram of Figure II-2, the Landsat C/RBV Subsystem includes: a sensor/baseplate assembly (Figure II-3), comprised of two sensors (Figure II-4) and a baseplate; two camera electronics packages (center and left hand side of Figure II-5), one for each sensor, and a Camera Controller Combiner (right hand side of Figure II-5). The two sensors and their corresponding camera electronics packages are identical except that the circuits in each electronics package are trimmed to be compatible with the requirements of the vidicon in the corresponding sensor.

The basis for the Landsat-C/RBV subsystem is the RBV subsystem being used on Landsat 1&2 satellites. Table II-1 shows the significant differences. As indicated, the Landsat-C/RBV differs from the previous RBV as follows:

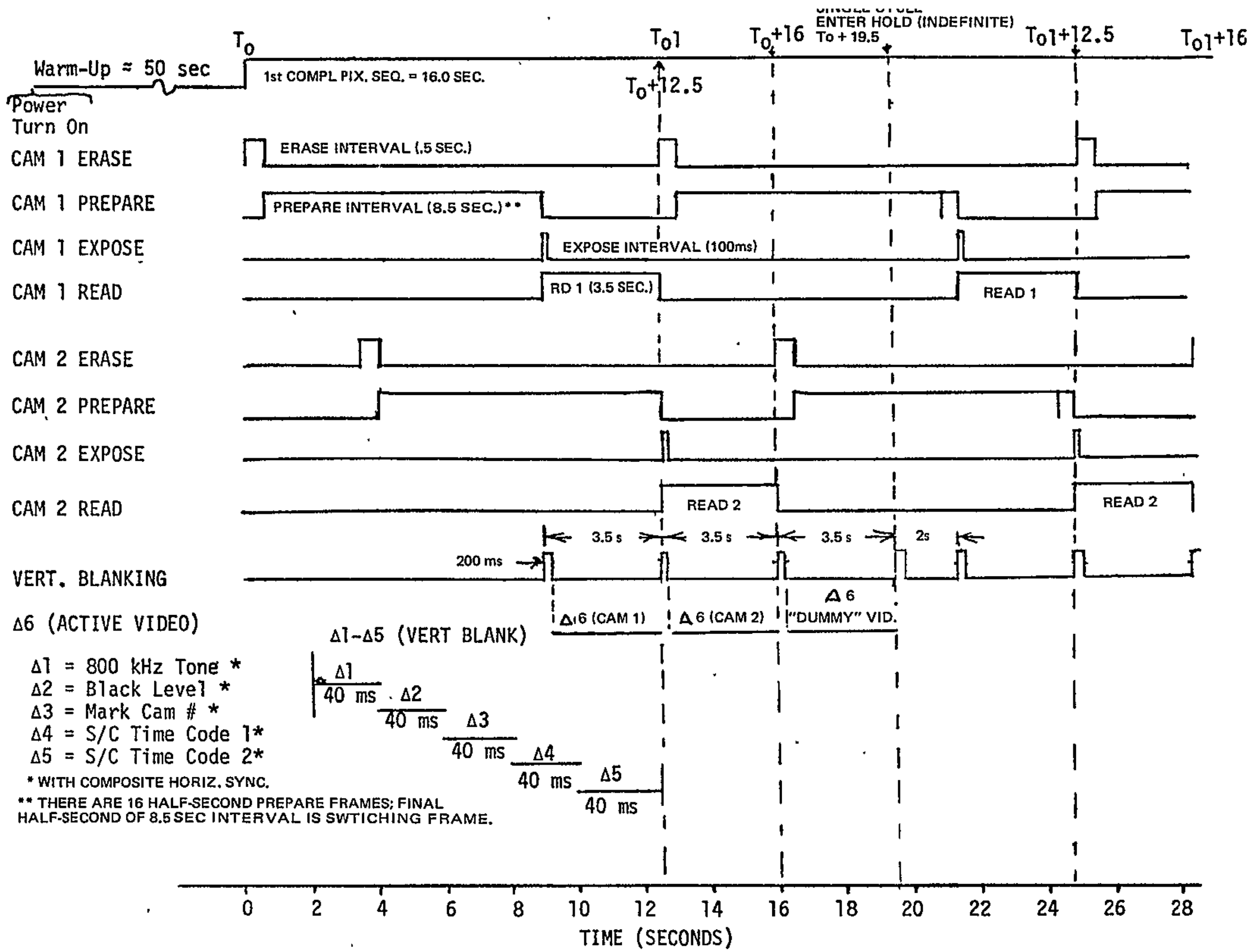

Figure II-1. Timing Diagram Landsat-C/RBV Two-Camera System

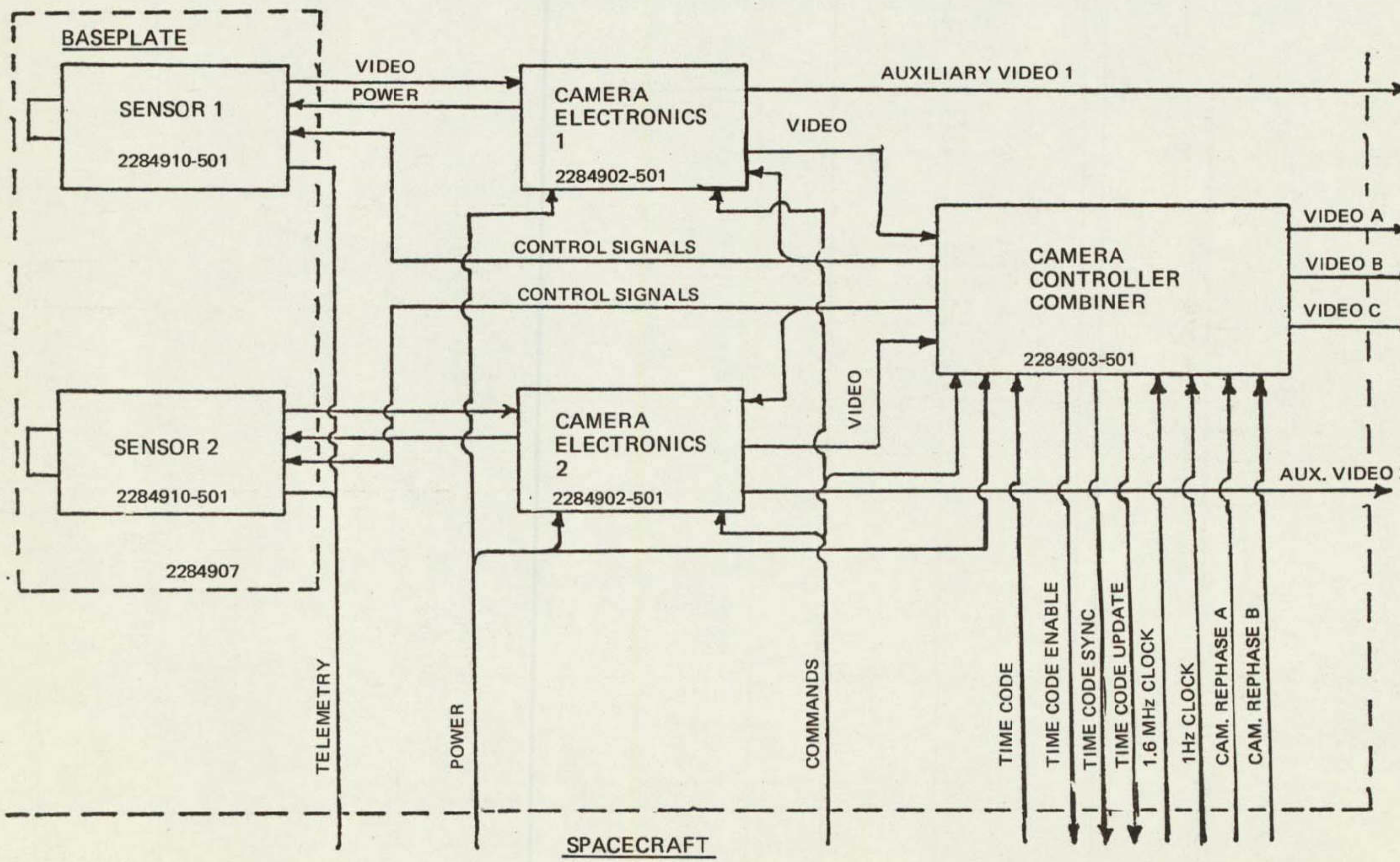

Figure II-2. Block Diagram, Landsat-C/RBV Two-Camera System

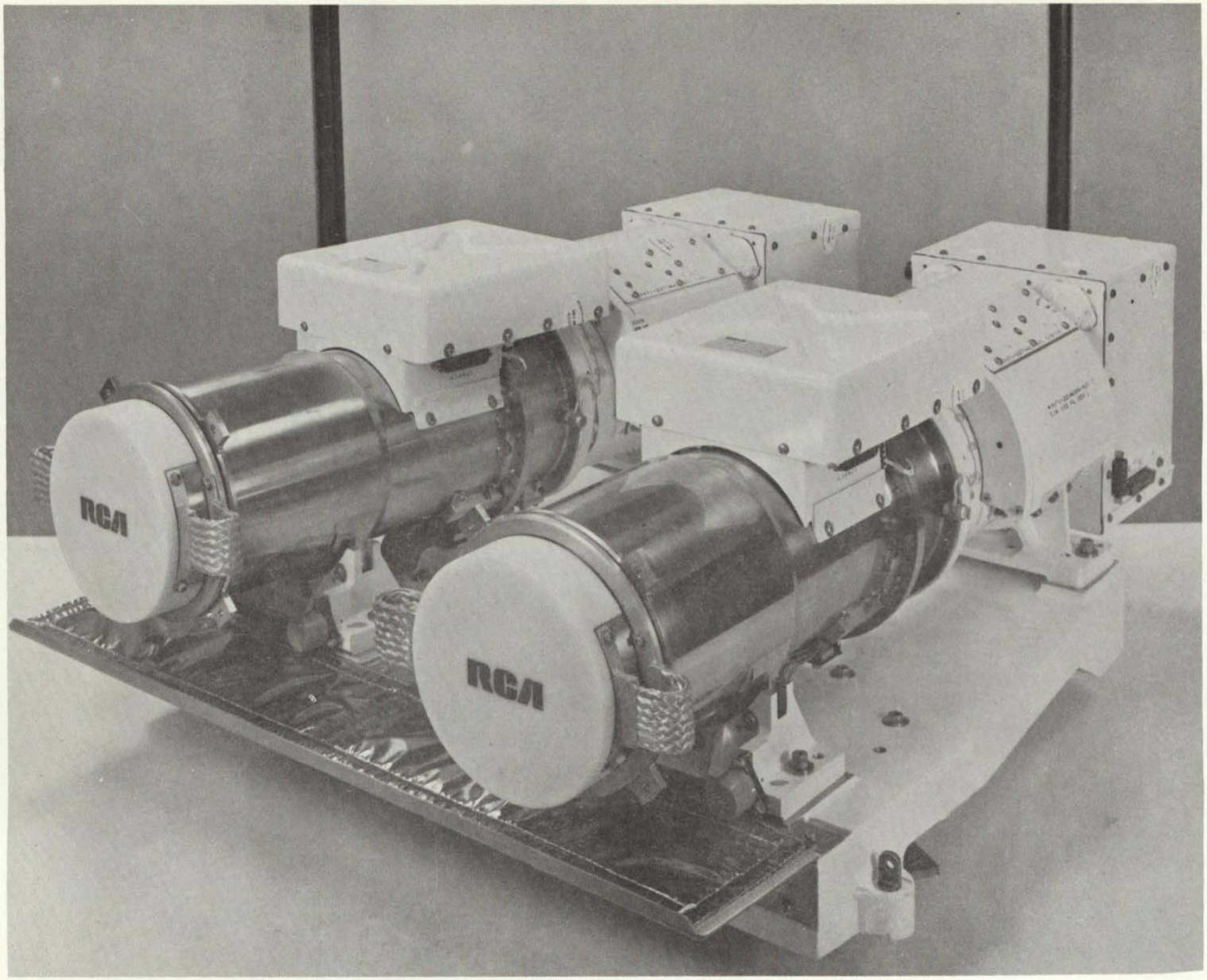

Figure II-3. Baseplate Assembly

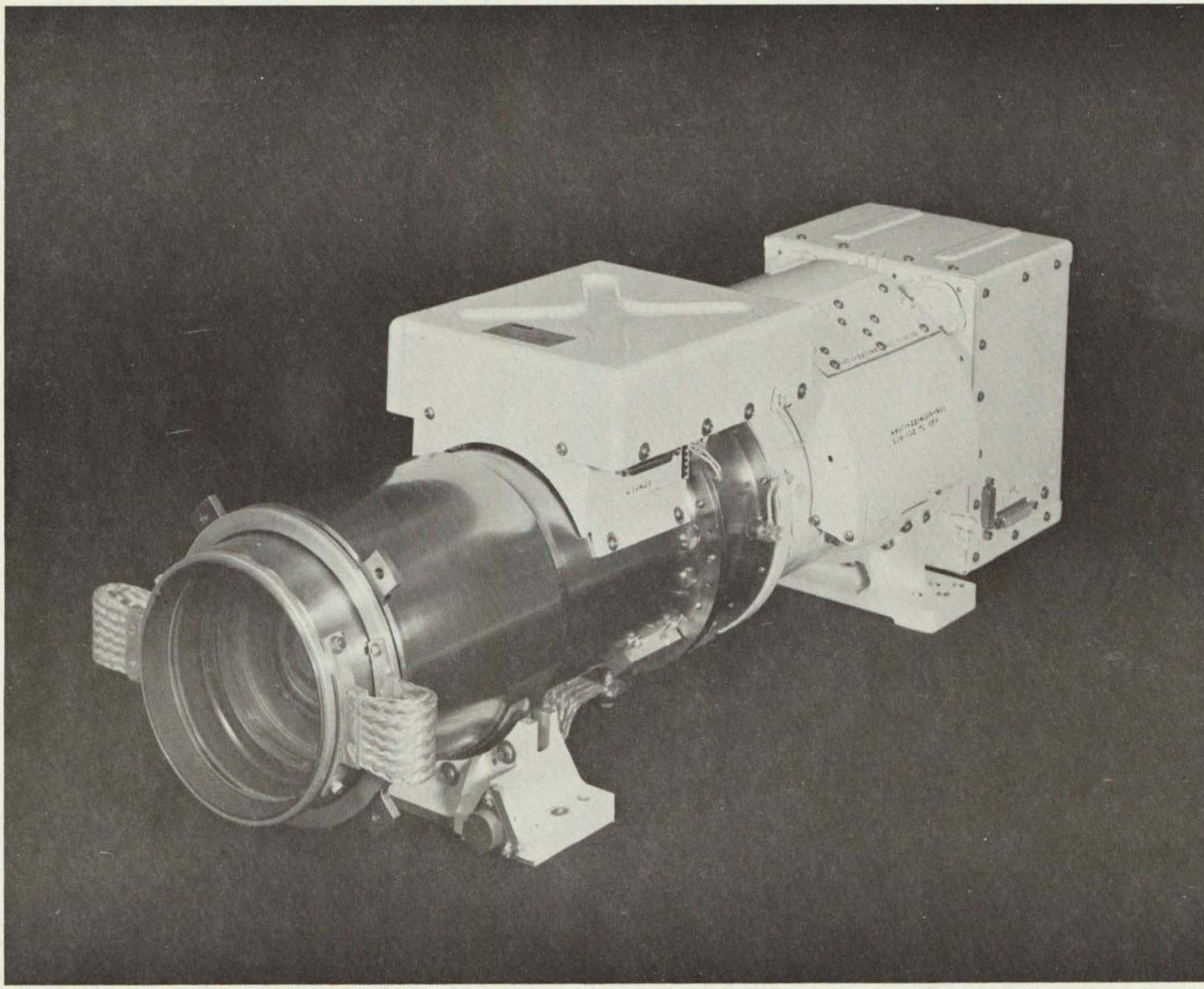

Figure II-4. Sensor Assembly

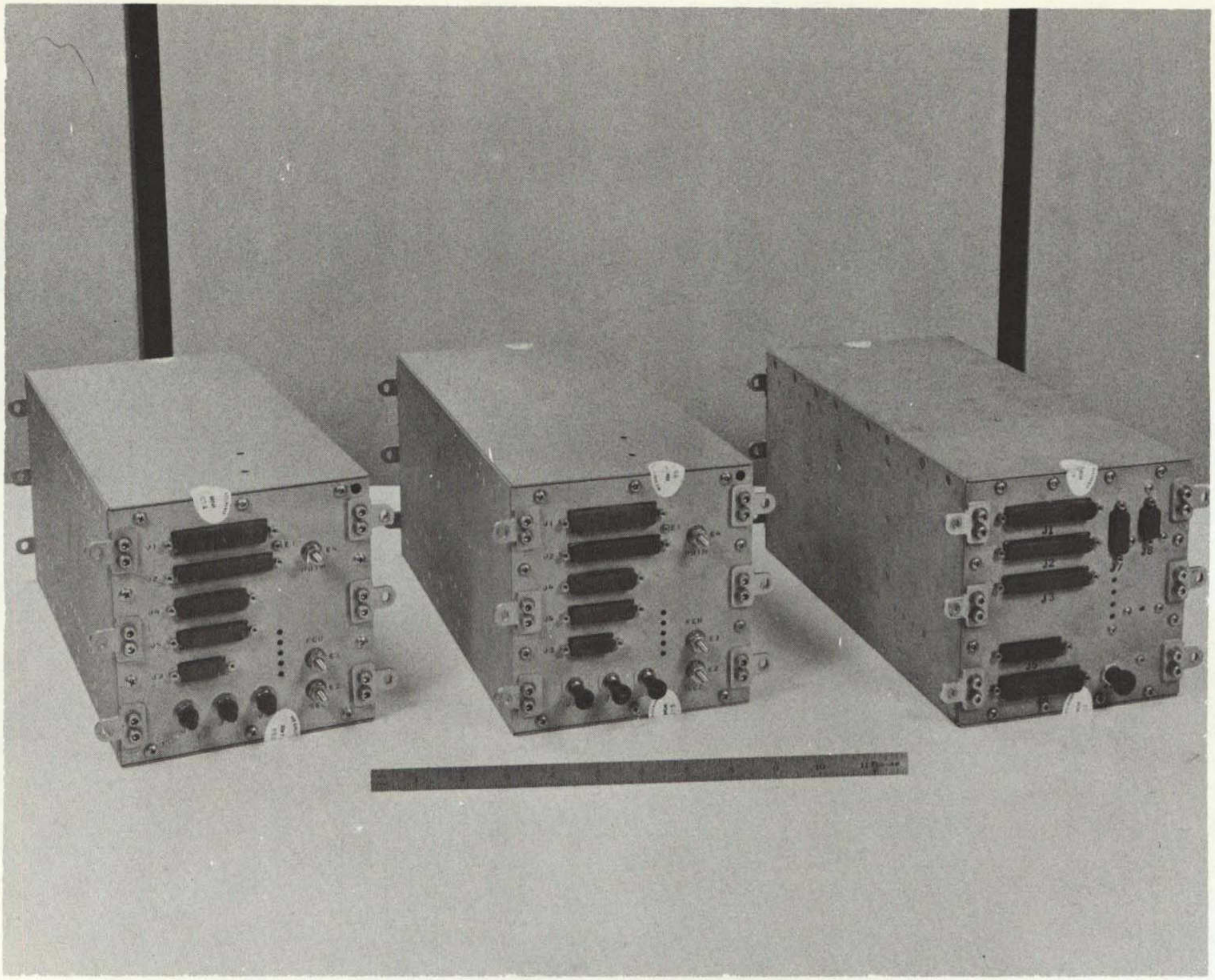

Figure II-5. Camera Electronics Assemblyes
and CCC

TABLE II-1. COMPARISON OF LANDSAT-C/RBV WITH LANDSAT A&B/RBV

Item	Landsat 1&2/RBV	Landsat-C/RBV
Number of Cameras	3	2
Ground Coverage/Frame	100 x 100 nmi	98.5 x 53 nmi
Ground Coverage/Camera	100 x 100 nmi	53 x 53 nmi (nominal)
Spectral Coverage	Camera 1: 475-575 mμ Camera 2: 580-680 mμ Camera 3: 690-830 mμ	Each Camera: 505-750 mμ
Erase, Prepare, Exposure	Simultaneous for 3 Cameras	Staggered for 2 Cameras
Readout	Staggered for 3 Cameras	Staggered for 2 Cameras
Nominal Exposure Time	12 ms	5.6 ms
Cycle Time	25 sec	12.5 sec
Nominal Lens EFL	125 mm	236 mm
Limiting Resolution	90 lp/mm	90 lp/mm
Video Bandwidth	3.2 MHz	3.2 MHz
Read Horizontal Line Rate	1250 lps	1250 lps
Read Time	3.5 sec total	3.5 sec total
Prepare Time	14 sec	8.5 sec
Erase Time	0.5 sec	0.5 sec
Shading Correction	Horizontal Correction independent of vertical position	Horizontal Correction programmed as a function of vertical position

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- Staggered Erase, Prepare and Expose cycles (the original RBV had Simultaneous Erase, Prepare and Expose);
- Panchromatic Coverage (the original RBV had three cameras, each of which covered a different spectral band;
- Nominal 236 mm focal length lens (the original RBV used a 125 mm lens); which provides 53 nmi square area coverage vs. 100 nmi coverage for the previous system.
- Side-by-side coverage of the two cameras per frame (the original had superimposed coverage per frame); and
- 12.5 Second picture cycle (the original had a 25 second cycle).
- Shutter exposures from 2.4 ms to 12 ms (in 5 steps), vs. 4 ms to 16 ms in previous cameras.
- Improved Shading Correction System

B. SYSTEM INTERFACES

In order to minimize changes to the Landsat/RBV interface and thereby facilitate integration of the spacecraft and the camera, the interfaces between the two-camera RBV system and the Landsat-C Spacecraft have been kept as close as possible to the corresponding interfaces between the three-camera RBV and Landsat 1&2. Those changes which were necessary, are compatible with the spacecraft requirement. Detailed interface information is contained in the Stage 4 release document (Ref. C5 of Sect. VII) and is summarized in the following paragraphs.

1. Signals

Timing signals from the RBV Subsystem to the spacecraft are listed on Table II-2. Note that two signals from the Landsat 1 &2/RBV (i.e., Run Tape A and Run Tape 2) have been deleted. The other signals, however, are essentially the same.

Timing signals from the spacecraft to the RBV Subsystem are listed in Table II-3.

The active video output format is unchanged from that of the original Landsat 1 and 2/RBV, as shown in Figure II-6. In addition, except for cycle time, the output data format is the same as that of Landsat 1&2, as shown in Figure II-7. A type of dummy video, consisting of a 1.6 MHz tone, has been inserted in place of the third camera video in order to minimize changes to the Receiving Site and Ground Test Equipment; a discussion of the Receiving Site Equipment modifications is contained in Section III.

2. Power

The power requirements are listed in Table II-4.

3. Commands

The commands required by the Landsat-C/RBV are listed in Table II-5. These commands are identical to those required by Landsat 1 and 2/RBV, except that the Camera 3 On/Off commands have been deleted and the Cal Enable/Disable commands have been changed to rephase A/B.

4. Telemetry

The telemetry points required by the Landsat-C/RBV are listed in Table II-6. This telemetry list is identical to that of

TABLE II-2. RBV TIMING SIGNALS TO SPACECRAFT

Timing Signals	Description
Time Code Sync	A +5 volt nominal, 80-us pulse, the edges of which are coincident with the horizontal-blanking interval of the composite video format. The pulse period is 800 us, and time-code sync is generated in all cases when horizontal sync is present.
Time Code Enable	A set of 3 pulses in each 12.5 second picture cycle. Each pulse is +5 volts nominal with a width of 80 ms. The pulses occur during the vertical blanking interval of each read and during a dummy vertical blanking at the end of the second read.
Time Code Update (Called T_O + 12 on Landsat 1 and 2)	A 500 millisecond wide high level (+5 volts) pulse whose trailing edge is coincident with the positive going edge of the spacecraft 1 Hz clock; on the first picture taking cycle and all succeeding odd cycles, this coincidence occurs 1.5 seconds before the exposure of camera 1, and on the second picture taking cycle and all succeeding even cycles, this coincidence occurs 1.0 seconds before camera 1 exposure.

TABLE II-3. TIMING SIGNALS FROM SPACECRAFT TO RBV

Signal	
1 Hz	Vertical blanking is synchronized with the 1 Hz at beginning of a cycle so that exposure occurs at a known point with respect to spacecraft timing.
1.6 MHz	Spacecraft clock signal which drives the programmer divider chain.
Rephase A	Used to synchronize camera horizontal sync with the video tape recorder head wheel position
Rephase B	Same as Rephase A.
Time Code	Supplied to Camera at proper time for insertion in video and data stream.

TABLE II-4. POWER REQUIREMENTS FOR LANDSAT-C/RBV

Bus (Note 2)	Power Consumption (Note 1)
-24.5V ± 2%, Regulated	136 watts average, including unreg. bus requirement 142.5 watts peak, excluding unreg. bus requirement
-28V, Unregulated	Peak Current = 2.4 amperes during shutter operation and .46 amps during erase lamp operation

NOTES:
1. Power consumed is shown for two cameras and CCC during normal operation. See power profile on Figure 7 of Reference VII-C5.
2. -24.5V is supplied on three lines: one to each camera and one to the CCC; the -28V is supplied on two lines; one to each camera.
3. Telemetry power (-24.5V) is on a separate line.

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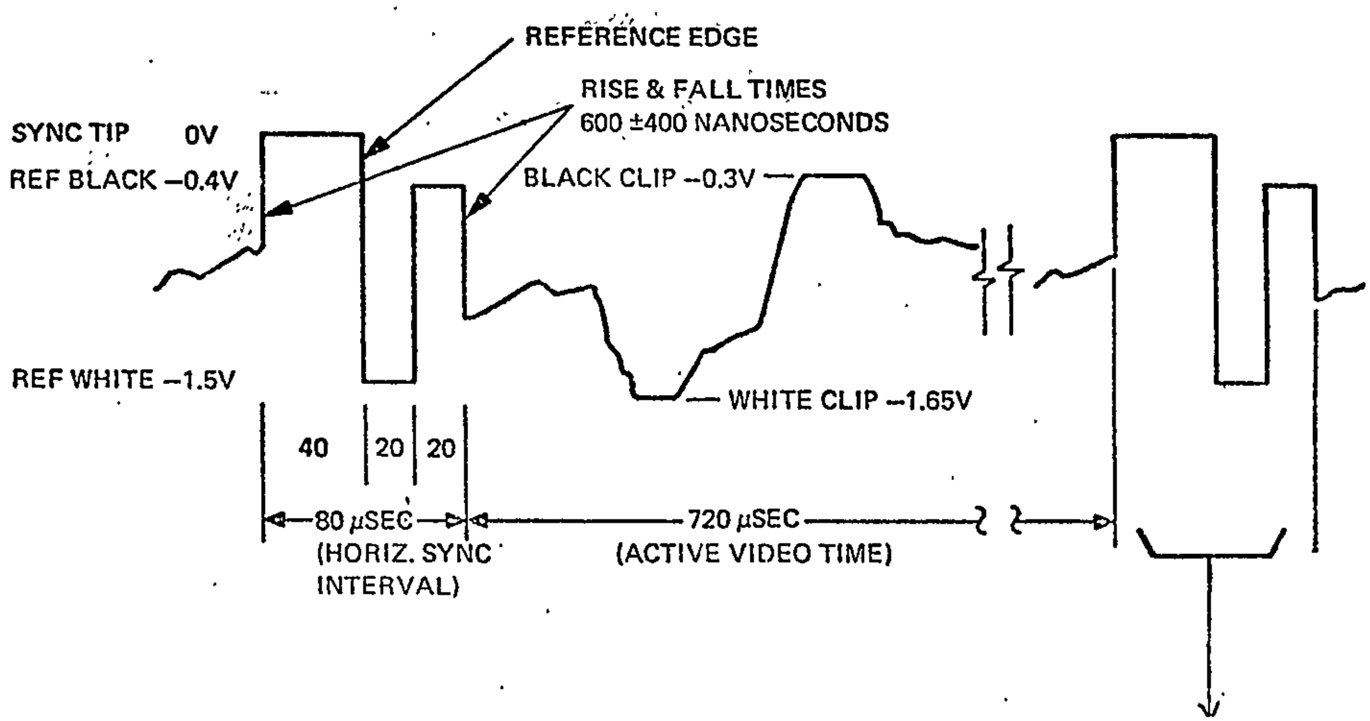

BLACK CLIP LEVEL	−0.3 ±0.05 VDC
WHITE CLIP LEVEL	−1.65 ±0.05 VDC
SYNC TIP	0 ±0.03 VDC
REFERENCE BLACK	−0.4 ±0.03 VDC
REFERENCE WHITE	−1.5 ±0.03 VDC

RISE AND FALL TIMES FOR HORIZONTAL SYNC INTERVAL (AND ALL VERTICAL SYNC INTERVALS) ARE 200 ±20 NANOSECONDS.

Figure II-6. Active Video Horizontal Line Format. Δ4, Δ5, and Δ6 Interval

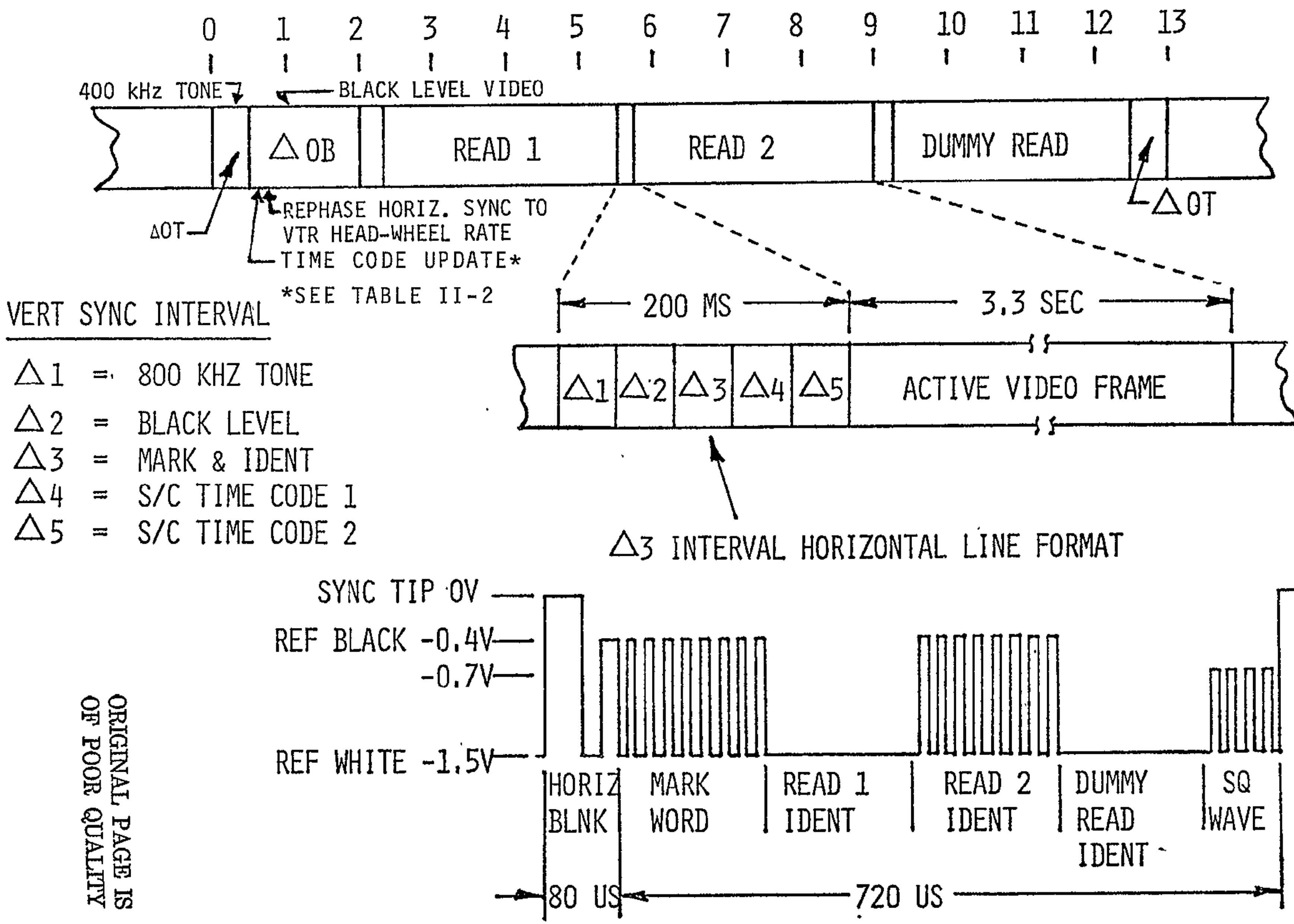

Figure II-7. Output Data Format

TABLE II-5. COMMANDS FOR TWO-CAMERA SUBSYSTEM

Command	Function
Single Cycle	Await Start-Prepare command before repeating Picture-Taking cycle
Continuous Cycle	Automatically repeat Picture-Taking cycle
Start Prepare	Initiate single Picture-Taking cycle if Single Cycle command was issued
Expose 1	Provide 2.4 ms exposure
Expose 2	Provide 4.0 ms exposure
Expose 3	Provide 5.6 ms exposure
Expose 4	Provide 8.0 ms exposure
Expose 5	Provide 12.0 ms exposure
Aperture Corrector In	Activate aperture-correction circuits
Aperture Corrector Out	Deactivate aperture-correction circuits
Start Calibrate	Initiate calibrate sequence if Calibrate Enable command was issued
Rephase A	Enable Rephase A Signal
Rephase B	Enable Rephase B Signal
Cathode Reactivation On	Enable cathode-reactivation circuit; disable 1.6-MHz protection
Cathode Reactivation Off	Disable cathode-reactivation circuit; enable 1.6-MHz protection
CCC Power On	Energize CCC
CCC Power Off	Deenergize CCC
Camera 1 On	Energize camera 1
Camera 1 Off	Deenergize camera 1
Camera 2 On	Energize camera 2
Camera 2 Off	Deenergize camera 2

TABLE II-6. TELEMETRY POINTS FOR THE RBV TWO-CAMERA SUBSYSTEM

Telemetry Point	Monitored Circuit Location (Note 4)	Level 0 (Note 1)	Level 1 (Note 1)
Expose TLM A	Exposure Control (CCC-A2)	See Table II-7	---
Expose TLM B	Exposure Control (CCC-A2)	See Table II-7	---
Exposure TLM C	Exposure Control (CCC-A2)	See Table II-7	---
AP Corr in/out	Aperture Corrector (CCC-A2)	AP Corr In	AP Corr Out
Rephase A/B	On-Board Calibration ckt (CCC-A1)	Rephase A Enable (0/-2 Vdc)	Rephase B Enable
Cam 1 On/Off	Camera 1 Power (C/E-A4)	Off	On
Cam 2 On/Off	Camera 2 Power (C/E-A4)	Off	On
Single/Cont Cycle	Mode Controller (CCC-A2)	Single Cycle	Continuous Cycle
CCC Board Temp	CCC Interface BD Temp (CCC-A7)	See Note 3	---
CCC P.S. Temp	CCC P.S. Temp (CCC-A13)	See Note 3	---
CCC Power On/Off	CCC Power (CCC-A13	CCC Off	CCC On
1.6-MHz Clock (CCC)	CCC Clock Input (CCC-A7)	1.6 MHz absent	1.6 MHz Present
Horiz Sync (CCC)	CCC Programmer (CCC-A7)	Horiz Sync Absent	Horiz Sync Present
Vert Sync (CCC)	CCC Programmer (CCC-A7)	All times other than vert sync interval	For 0.2 sec during sync interval
1-Hz Sync (CCC)	CCC Clock Input (CCC-A7)	Programmer & 1 Hz not in sync	PGM & 1 Hz in sync
-24.5V Input (CCC)	CCC Power Input (CCC-A7)	-24.5V absent	-24.5V Present
± 15V (CCC)	CCC P.S. Output (CCC-A13)	Off	-4.2V: ± 15V On -3V: +15V On and -15V Off -1.2V: -15V On, and +15V Off
+6V, -5.25V (CCC)	CCC P.S. Output (CCC-A13)	Off	-3V: +6V On and -5.25V On -2.2V: +6V Off and -5.25V On -1.5V: +6V On -5.25V Off
Cathode Reactivation On/Off	CCC Cathode React. Ckt (CCC-A2)	Cathode React. Off	Cathode React. On
Faceplate Temp	Note 2 (Sensor)	See Note 3	---
Yoke/Focus Temp	Note 2 (Sensor)	See Note 3	---
Electronics Temp	Note 2 (C/E-A7)	See Note 3	---

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TABLE II-6. TELEMETRY POINTS FOR THE RBV TWO-CAMERA SUBSYSTEM (Continued)

Telemetry Point	Monitored Circuit Location (Note 4)	Level 0 (Note 1)	Level 1 (Note 1)
LVPS Temp	Note 2 (C/E-A4)	See Note 3	---
Focus Current	Note 2 (C/E-A9)	See Note 3	---
Combined Alignment	(Horiz & Vert Alignment) Note 2 (C/E-A7)	Off	VAC & HAC on: -4V VAC On, HAC Off: -1.9V VAC Off, HAC On: -3V
Filament Current	Note 2 (S/E-A1)	See Note 3	---
G_1 Voltage	Note 2 (S/E-A1)	See Note 3	---
Target Voltage	Target Voltage Cont Note 2 (S/E TVC)	See Note 3	---
+500 Volts	Electrode Div (Note 2) (S/E-A6)	See Note 3	---
Cathode Current	Note 2 (S/E-A2)	See Note 3	---
Horiz Defl Out	Note 2 (S/E-A3)	See Note 3	---
Vert Defl Out	Note 2 (S/E-A4)	See Note 3	---
Thermal Control Current	Note 2 (C/E-A8)	See Note 3	---
Defl P.S.	+10V Sources; Note 2 (C/E-A2)	Off	+10V On: -4.0V +10V On, -10V Off: -1.5V +10V Off, -10V On: -3V
LVPS	+6V, -6.3V Sources; Note 2 (C/E-A2)	Off	+6V, -6.3V On: -3.7V +6V On, -6.3V Off: -1.5V +6V Off, -6.3V On: -3V
High V Chopper	Note 2 (S/E-HVPS)	Off	On
-24.5V Common Pwr	Note 2 (C/E-A4)	Off	On
-28V Shutter Current On/Off	Note 2 (C/E-A6)	Off	On
Video	Note 2 (C/E-A13)	Note 3	---

Notes:
1. Where not specified, a level "0" is 0 to -1.0 Vdc and a level "1" is -5 to -10 Vdc.
2. There are two of each of these telemetry points - one for each camera.
3. Analog value between 0 and -5 volts; calibrated.
4. C/E: Camera Electronics; S/E: Sensor Electronics; CCC: Camera Controller r Combiner; A7: Board A7.).

TABLE II-7. EXPOSURE TELEMETRY MATRIX

Exposure		Telemetry Channels* (See Table II-6)		
Number	Value (M sec)	Expose Telemetry A	Expose Telemetry B	Expose Telemetry C
1	2.4	0	0	1
2	4.0	0	1	X
3	5.6	1	0	X
4	8.0	1	1	X
5	12.0	0	0	0

Legend: "X" - Level does not matter
"1" - -5 to -10 Vdc
"0" - 0 to =1.0 Vdc

The Landsat 1&2/RBV, except that the third camera telemetry points have been deleted and the Cal Enable/Disable point has been changed to a Rephase A/B point.

5. Mechanical

A weight breakdown of the RBV Flight Model is contained in Table II-8 and a list of dimensions is contained in Table II-9. In order to minimize the impact on the Spacecraft/RBV interface, certain mechanical constraints were imposed on the design of the Landsat-C/RBV; these include:

- the same baseplate feet to spacecraft mounting as used on Landsat 1&2 must be used on Landsat-C, and the same drill template must be used;

TABLE II-8. WEIGHTS OF TWO-CAMERA FLIGHT SUBSYSTEM COMPONENTS

Assembly	Drawing	Actual Weight
Camera Sensor 1	2284910-501	47.74
Camera Sensor 2	2284910-501	47.74
Baseplate Assy.*	2284901-501*	29.15*
Camera Electronics 1	2284902-501	13.80
Camera Electronics 2	2284902-501	13.74
Camera Controller Combiner	2284903-501	10.17
TOTAL SYSTEM	2284900-501	162.34 pounds

*Less sensors, but includes isolator mounts, radiator and thermal blanket.

TABLE II-9. DIMENSIONS OF 2-CAMERA SUBSYSTEM COMPONENTS

Assembly Name	Length (in.)	Width (in.)	Height (in.)
Sensor/Baseplate Assembly (Note 1)	25.1 ± 0.1	24.64 ± 0.1	12.5 max.
Camera Electronics (Note 2)	13	6	6
Camera Controller Combiner (Note 3)	13	6	6
Typical Sensor Unit	26.6 ± 0.1	8.0 ± 0.1	8.5 ±0.1

Notes:

1. Dimensions of Sensor/Baseplate Assembly Include Feet and Radiator.
2. Dimensions of Camera Electronics Exclude Connectors and Mounting Brackets.
3. Dimensions of CCC exclude connectors and Mounting Brackets.

- the sensors must not extend any further into the spacecraft than the plane formed by the rear part of the Sensor Electronics of the two outboard Landsat 1&2 sensors.

Further details of the Mechanical Considerations are contained in Section II-D.

6. Thermal

In general, the thermal interface of the Landsat C/RBV is similar to that of the Landsat 1&2 RBV. During the design period, a thermal analysis of the Landsat-C sensor was performed in order to verify conformance with spacecraft constraints.

C. Camera Ground Coverage and Pointing Angles

Nominal coverage provided by the two-camera RBV system is shown in Figure II-8. In this figure, it has been assumed that pictures A and B are taken at equal time intervals before and after the time when the satellite is directly over the equator. They appear side by side, despite the difference of exposure times, as a result of differential aiming of the cameras, as will be described in subsequent paragraphs. Pictures C and D (taken prior to A and B) are displaced relative to the Orbital track because of the eastward motion of the earth during the 12.5-second interval between picture pair C and D and picture pair A and B. Pictures E and F are assumed to be centered on the equator in the same manner as Pictures A and B.

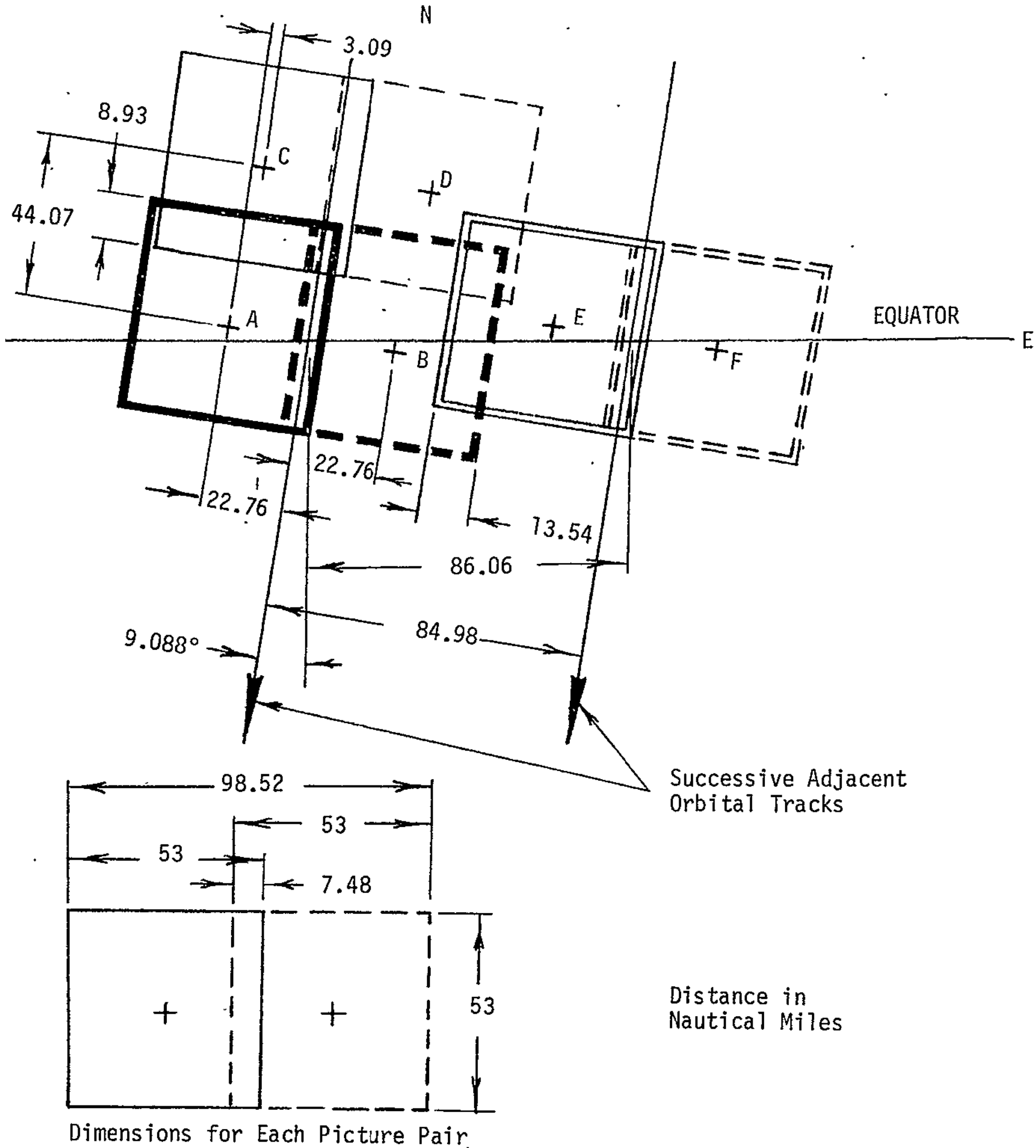


Figure II-8. Picture Coverage at Equator With All Parameters at Nominal Values

The coverage at the equator depicted in Figure II-8 is determined for the case in which all system parameters are at their nominal values, and in which spacecraft pitch and roll angles are identically zero. Variations in picture size, and in picture location relative to the orbital track, will result from deviations of system parameters from their nominal values, and from non-zero pitch and roll angles. Such variations will cause variation in picture overlap; and picture overlap will also change as a function of location in the orbit because of variations, with orbital location, of the separation of successive adjacent orbits, and of subpoint vector velocity (due to earth rotation) relative to the orbital track.

Overlap between the two halves of each picture pair has been set so that the most unfavorable combination of roll rates and departures of system parameters from nominal values will not result in coverage gaps on the sunlit side of the earth. As shown in Ref. VII C6 (Appendix A-2 of the Design Concept Review Package for the Return-Beam-Vidicon Camera System for Landsat-C, dated May 20, 1975), the maximum anticipated change in the overlap of pictures in a picture pair, in the absence of earth rotation, would be 6.62 nautical miles.

When pictures are taken at the equator, earth rotation will either increase or decrease this overlap, depending upon which picture is taken first. When pictures are taken at northern or southern extremities of the orbit, however, the contribution of the earth's rotation to this overlap is zero. The choice of the order in which pictures will be taken is dictated by the availability of space for test collimators in the spacecraft integration fixture, and the required order is such that the earth's rotation increases overlap of pictures at the equator. In order to insure that gaps in coverage will not occur at the polar extremities (where earth's rotation does not affect overlap), nominal overlap at these locations must be 6.62 nautical miles, and overlap at the equator will be increased as a result

of the earth's rotation. The amount of the increase is $3.5 \times 0.25 \times \cos 9.088^{\circ} = 0.86$ nautical miles (3.5 is separation of exposures in seconds; 0.25 is velocity of the earth's surface in nautical miles per second; and $\cos 9.088^{\circ}$ accounts for the fact that earth velocity is not perpendicular to satellite velocity); so nominal overlap at the equator is 6.62 + 0.86 = 7.48 nautical miles; nominal coverage is (2 x 53) - 7.48 = 98.52 nautical miles; and nominal separation of picture centers is 53 - 7.48 = 45.52 nautical miles. These values are shown in Figure II-8.

Nominal overlap in the along track direction between picture pairs is 8.93 nautical miles. The maximum anticipated change in the overlap, resulting from spacecraft pitch rate and from departures of system parameters from nominal values, is 3.46 nautical miles; so minimum anticipated overlap is 5.47 nautical miles. (These values differ slightly from those in the previously mentioned document because the effect of earth rotation was not taken into account in the previous calculations.)

Nominal coverage overlap between adjacent successive orbits (at the equator) is equal to the difference between the design coverage width of 98.52 nautical miles, and the orbit track separation of 84.98 ($86.06 \cos 9.088^{\circ}$) nautical miles, or 13.54 nautical miles. Maximum anticipated change of overlap, resulting from departures of system parameters from nominal values, is 6.32 nautical miles, leaving an overlap at the equator of at least 7.22 nautical miles which will accommodate differences as large as 0.84° between the spacecraft roll angles in the two orbits without introducing gaps in coverage. This overlap increases for picture locations on either side of the equator, reaching 100% at the extremities of the orbit.

Figure II-9 represents the geometry used to determine camera pointing angles relative to spacecraft axes. Points A and B, which lie on a perpendicular to the orbital plane through the

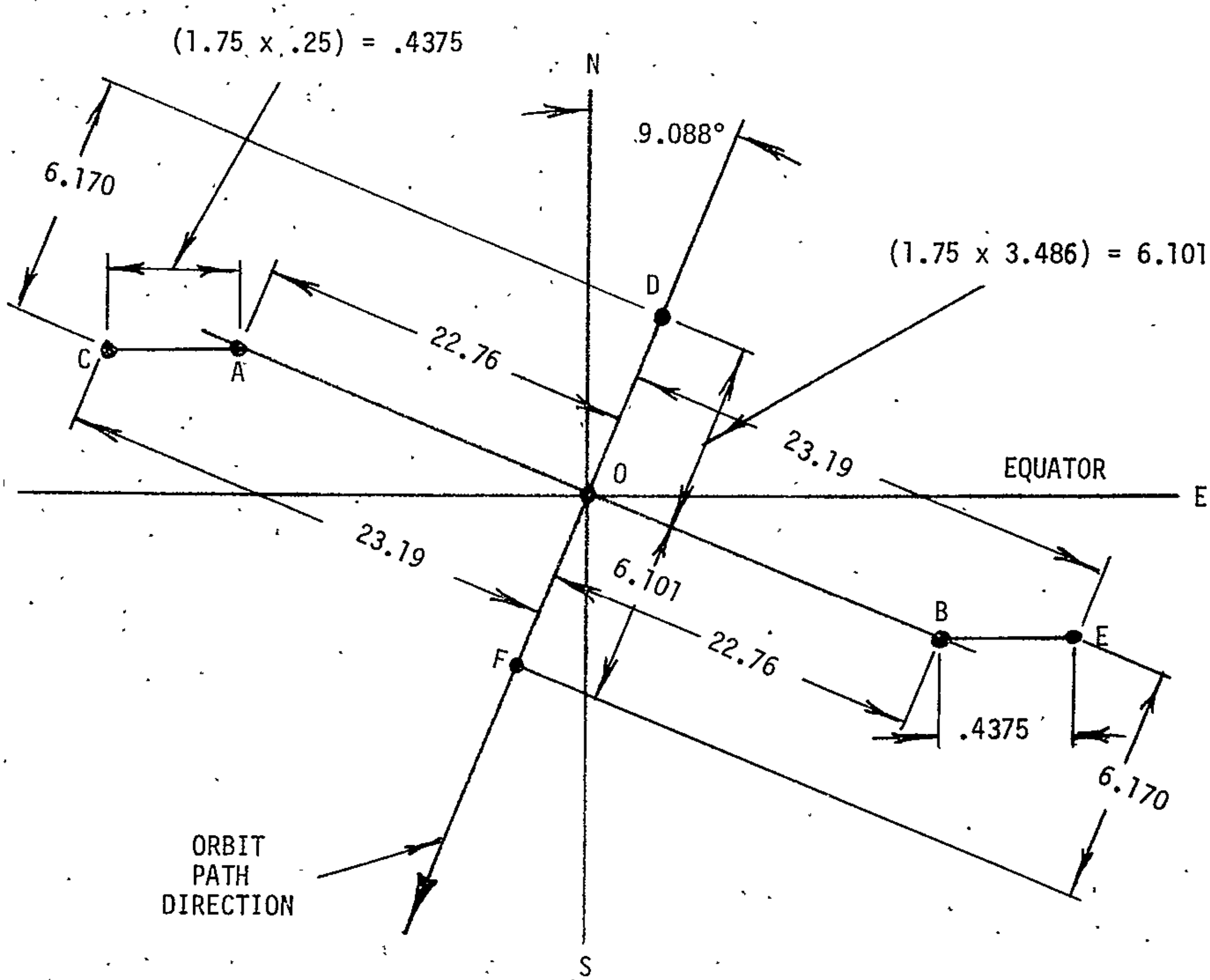
intersection of that plane with the equator, are the locations, on the earth's surface, of the centers of the two pictures in a picture pair when the spacecraft is directly over the equator at point 0. The picture centered at point A is to be taken first with camera #1, followed 3.5 seconds later by the picture centered at point B taken with camera #2. 1.75 seconds (one-half the time separation of the two pictures) before the spacecraft reaches 0, it is at point D; and the intended picture center, point A, is at point C. The location of point C relative to point D, in conjunction with spacecraft altitude of 492.35 nautical miles, determines for camera #1 the required pointing angles of 0.71° forward and 2.69° to the west. Correspondingly, 1.75 seconds after the spacecraft passes point 0 it is at point F, and the intended picture center is at point E. As a result of the symmetry of the geometry, the required pointing angles for camera #2 are 0.71° to the rear and 2.69° to the east. Figure II-10 shows the resulting camera orientations with respect to spacecraft axes, where in the "S/C Top View" we are looking at the back ends of the cameras.

In order to comply with the foregoing coverage and overlap constraints, the two cameras are mounted on the baseplate in accordance with the following requirements.

a) Each camera axis shall be displaced in roll angle by 2.69 ± 0.05 degrees relative to the axes established by G.E. alignment cube (Ref. 47E222092).

b) Each camera axis shall be displaced in pitch angle by 0.71 ± 0.05 degree relative to the axes established by G.E. alignment cube (Ref. 47E222092).

c) Camera alignment in yaw, as established by the center row of reticles, shall coincide with the yaw reference established by GE alignment cube (Ref. 47E222092) within 0.05 degree.



$$\text{ARC TAN } \frac{6.170}{492.35} = 0.718°$$

$$\text{ARC TAN } \frac{23.19}{492.35} = 2.697°$$

DISTANCES IN
NAUTICAL MILES
(NOT TO SCALE)

Figure II-9. Camera Pointing Angle Determination

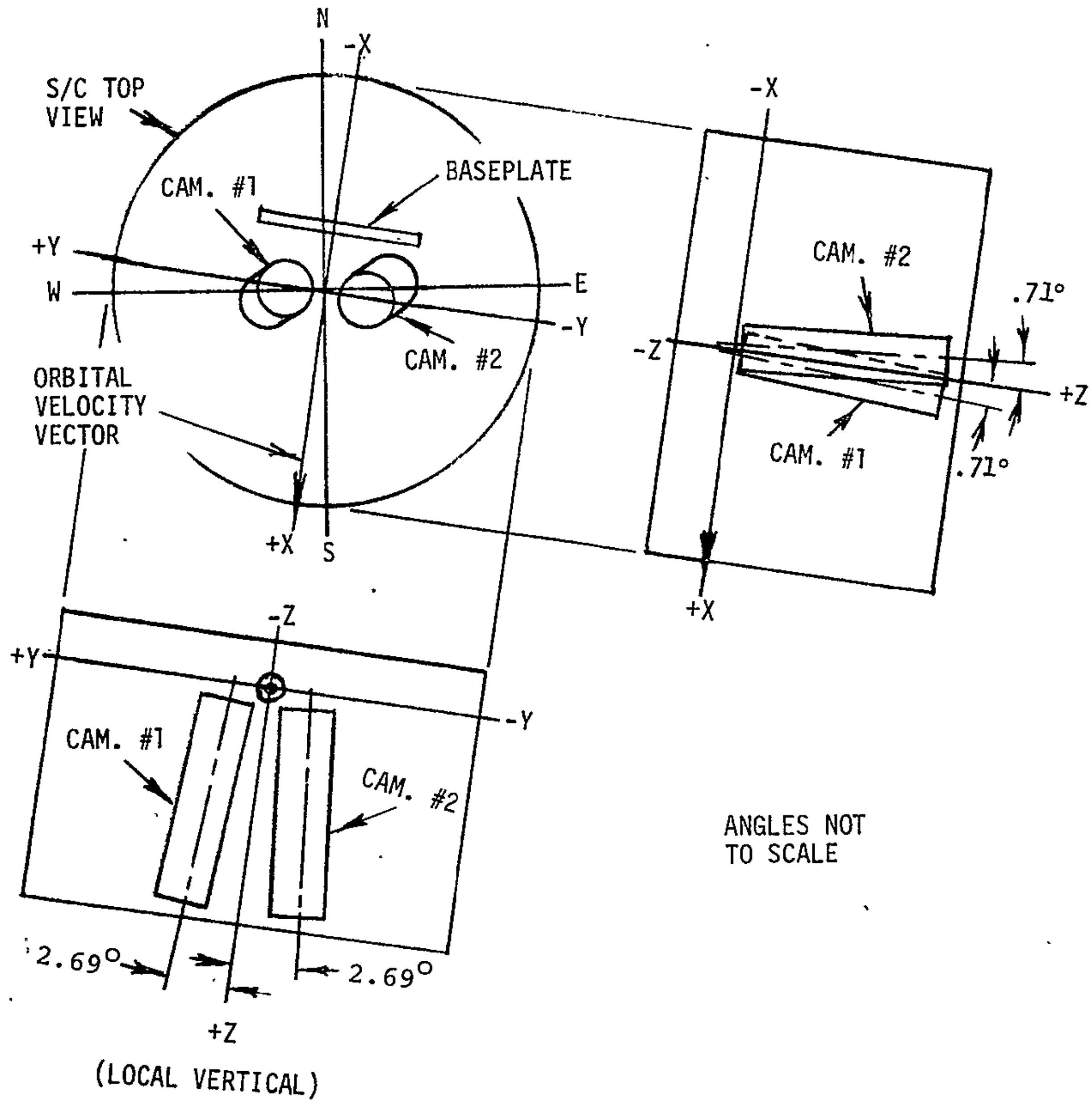


Figure II-10. Camera Orientation

D. FUNCTIONAL PERFORMANCE

As shown in Figure II-11, each RBV camera includes a sensor unit and a Camera Electronics Unit. Each sensor contains a two-inch Return-Beam Vidicon, focus and deflection coils, a high voltage power supply, deflection circuits, a preamplifier, a beam current regulator, a target voltage control unit, a vidicon-faceplate temperature control unit, target lamps, a shutter, and a lens. The relationship between the Vidicon, the focus coils, and the deflection coils is shown schematically on Figure II-12.

Each Camera Electronics package contains a low-voltage power supply, a video processor, a shutter drive circuit, focus and alignment current regulators, a target lamp control, and faceplate-temperature-control circuits. The circuits in each electronics package are trimmed to be compatible with the requirements of the vidicon in the corresponding sensor.

The CCC contains a command decoder, a programmer, a video combiner, and a power supply. The purpose of the CCC is to process commands, generate subsystem timing signals (including those required by the various sections of each RBV camera), and generate a combined video signal, as shown on Figure II-13.

It should be noted that ground provision has been made to radiometrically and geometrically correct the video signal which is transmitted back from the orbiting Landsat satellite. This correction is performed using calibration data supplied by RCA. The radiometric calibration data is supplied on magnetic tape, and is used to correct for residual shading of each camera. It consists of precise measurements of the video level at 324 different points in a frame for several different light level inputs, including 100% highlight and black. The geometric calibration data consists of the precisely measured position of each of the 81 reticles on the faceplate of the vidicon. This information can be used to correct for any residual geometric distortions in the sensor system.

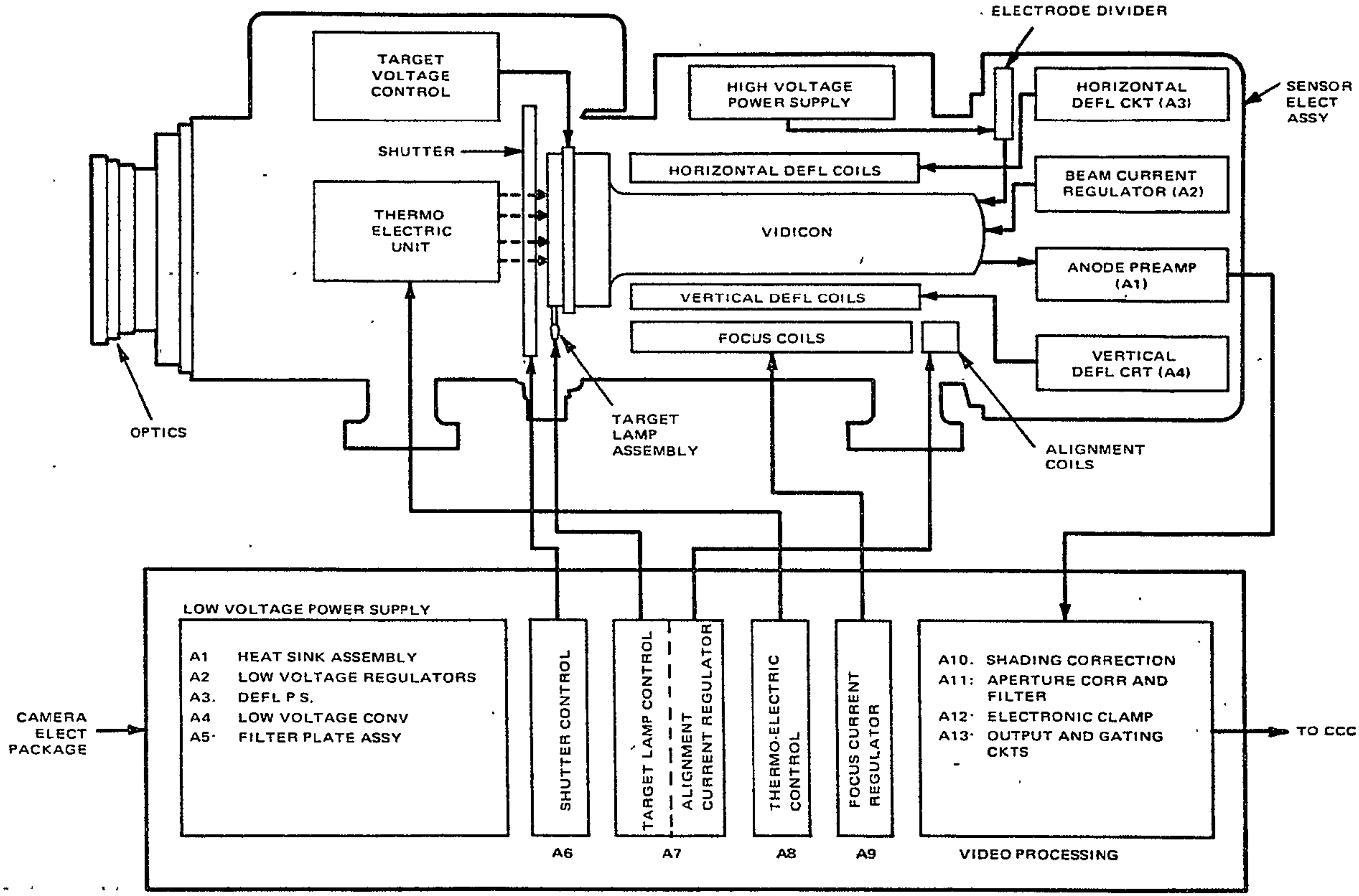


Figure II-11. Single Camera, Block Diagram

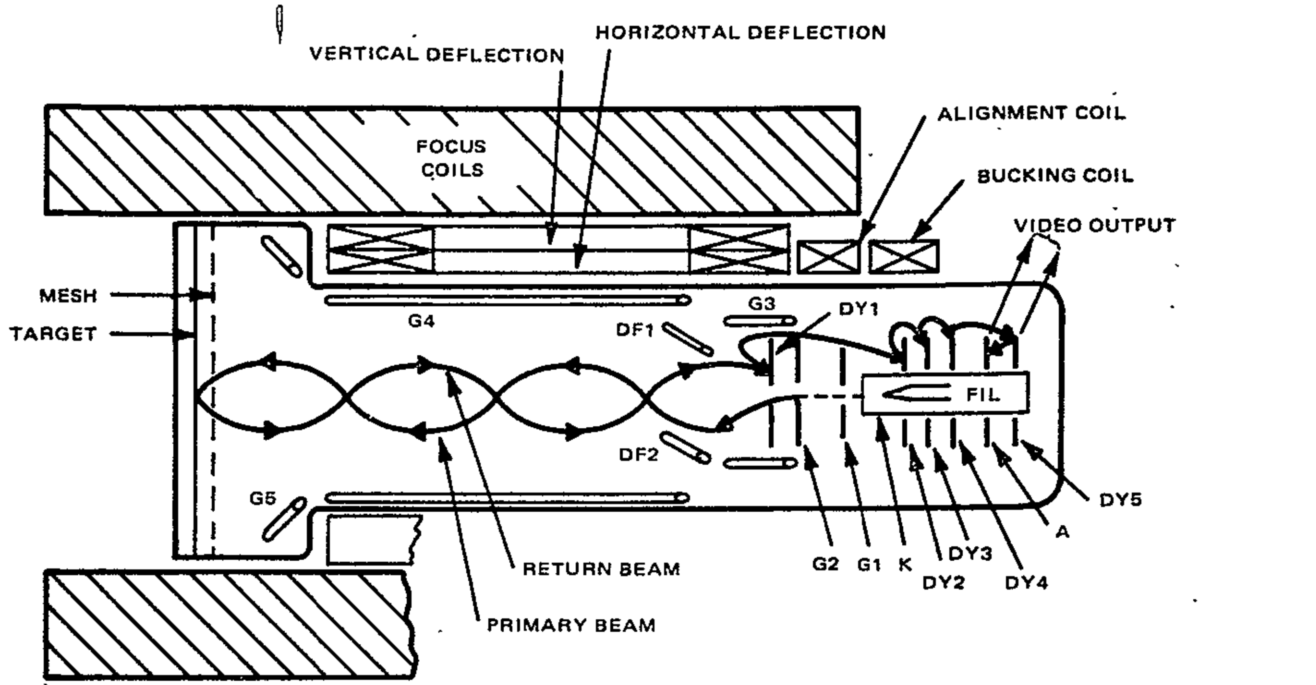


Figure II-12. RBV, Schematic Diagram

There is also a video level calibration capability available upon command in which a known light level (from the target lamps) is used to expose the target for a controlled interval; the resulting video signal is compared with previously recorded information in order to evaluate the electron optics and the video processor of the sensors.

Other features of the RBV system include the command capability of reactivating the cathode should the cathode emission start to decrease, and the command capability of aperture correcting the video signal when desired.

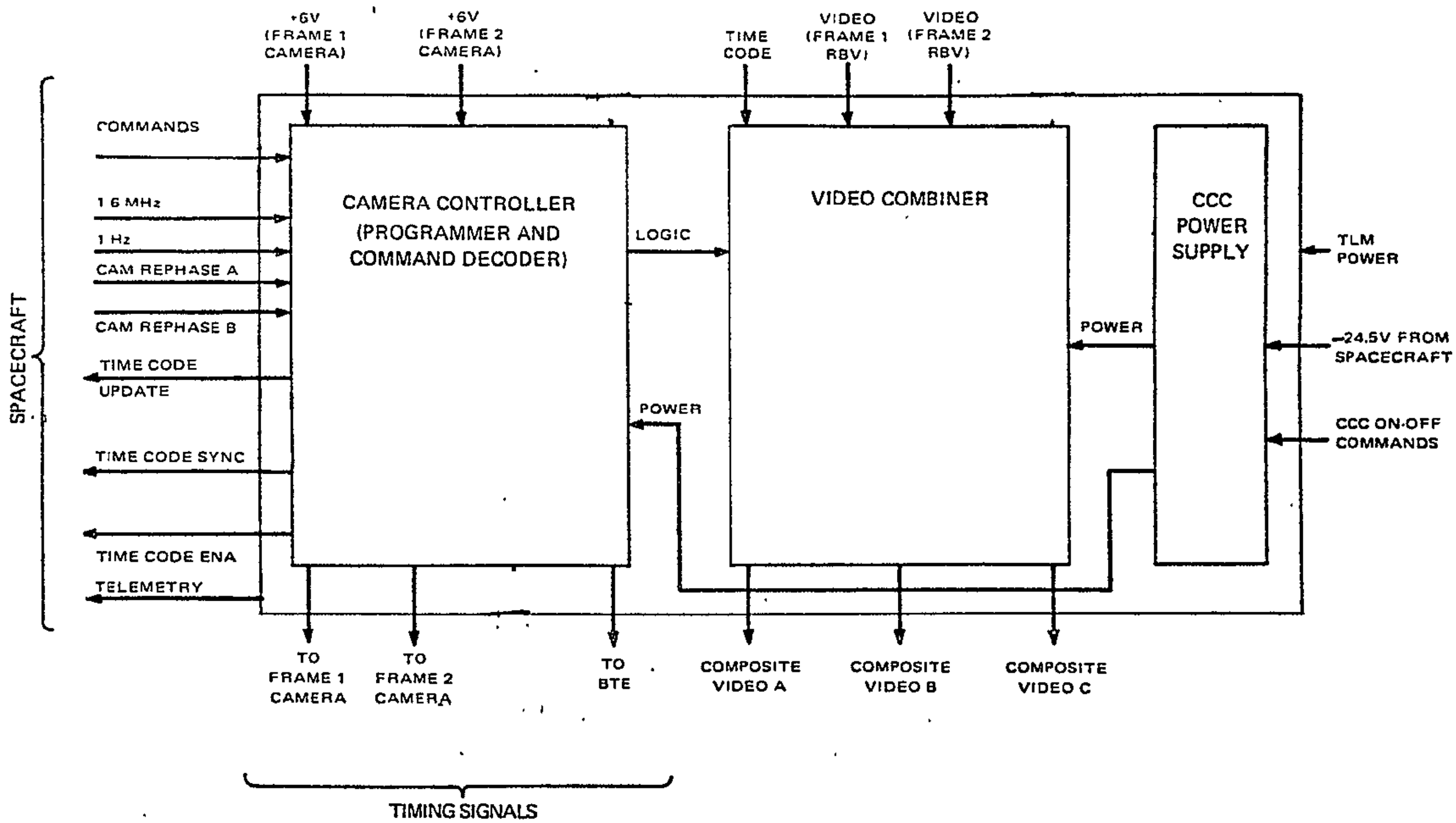


Figure II-13. Simplified Block Diagram, Camera Combiner and Controller (CCC)

Except for the Camera Controller Combiner (CCC) circuitry and the Shading Correction circuitry, the detailed description of the various parts of the Landsat 1&2 Three-Camera RBV Subsystem contained in the corresponding O&M Manual*, also applies to the Landsat-C/RBV; Included in this O&M Manual is a general discussion of Return Beam Vidicon Theory. The Landsat-C Shading Correction Circuitry and the CCC are discussed in this report (Section II-F).

E. MECHANICAL PERFORMANCE

1. RBV Camera Assembly

a. General Description

The Landsat-C/RBV camera is a nominal 26.63 inches in length, 8.48 inches high and has a maximum width of 7.94 in. The camera has been modified mechanically from the original Landsat 1&2 design only to the extent of accommodating the new lens. The electromagnetic focusing assembly, sensor electronics package, shutter assembly, TVC assembly and high voltage power supply assembly from a mechanical standpoint remain virtually unchanged. The outward appearance of the camera remains similar to the Landsat 1&2 cameras with the exception of the larger lens and a change of the paint color from blue to white.

b. Imaging Assembly Design Details

The major subassemblies that make up an imaging assembly are the lens, lens mount with thermal compensation mechanism, shutter, thermal electric cooler (TEC) with front focus coil, two-inch RBV tube with yoke and the front supporting foot.

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*Operation and Maintenance Manual for the Return Beam Vidicon Multispectral Three Camera Subsystem for ERTS A&B; RCA-AED #M-8012F; Issued September 1972; Prepared for NASA/GSFC (Greenbelt, Md.); Contract NAS 5-21094

The ten-inch focal length lens for Landsat-C is considerably larger and heavier than the five-inch lens used on the Landsat-I and II cameras. The new lens weighs more than twice that of its predecessor necessitating a significant change in the lens mount. The design was based on important parameters including weight, structural strength, thermal characteristics, thermal compensation capability, overall size (especially diameter), alignment capability and maintaining a center of mass near the shutter area as in the previous cameras. (The center of mass requirement was necessitated by baseplate design criteria). The design concept selected was a modular approach which simplified the overall lens mount, keeping size and weight to a minimum. The design required no change to the electromagnetic focusing assembly interface.

- Front Focus Coil Housing - In the previous camera the outer lens mount housing and the front focus coil area were one piece. The Landsat-C camera has the front focus coil housing as a separate module (Figure II-14). This module houses the front coil, thermal electric cooler and shutter. All three components require a very special relationship with respect to the RBV tube, thus this part of the overall structure had to be identical to the previous cameras. Making it a separate module was thus a logical choice and also provided the means to easily center the lens without the use of double, concentric sleeves around the lens. The housing is made from titanium 6Al4V and obtains its bright finish from polishing as opposed to copper and chrome plating used on the previous camera.

- Lens Mount - The lens mount, Figure II-15, is also made from titanium 6Al4V and has a polished exterior finish. As a separate module, it is adjustable with respect to the front focus coil module making possible exact centering of the lens onto the center reticle of the vidicon. Attachment of the lens mount is by a bolted flanged coupling to the front focus coil housing.

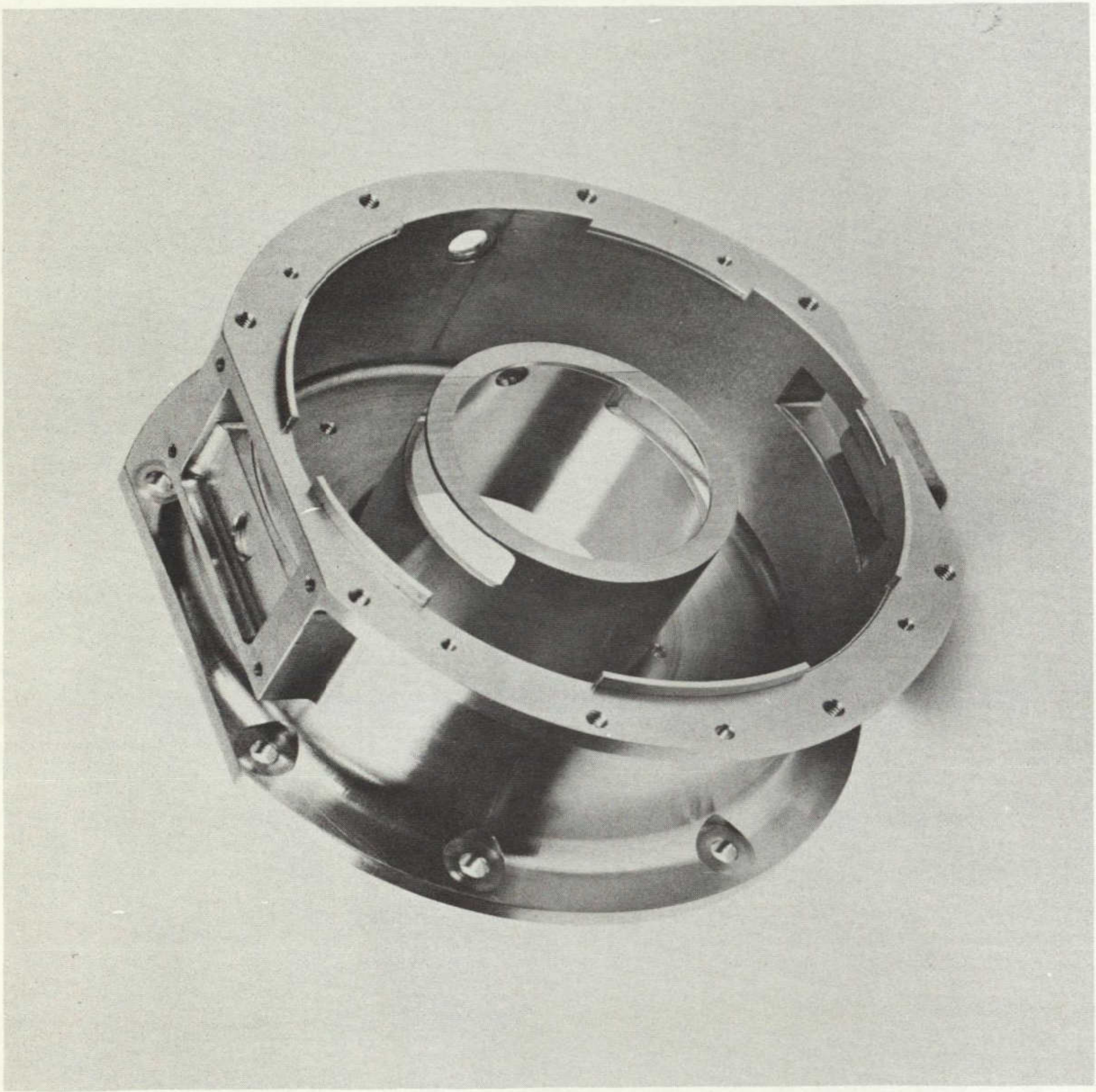


Figure II-14. Front Focus Coil Housing

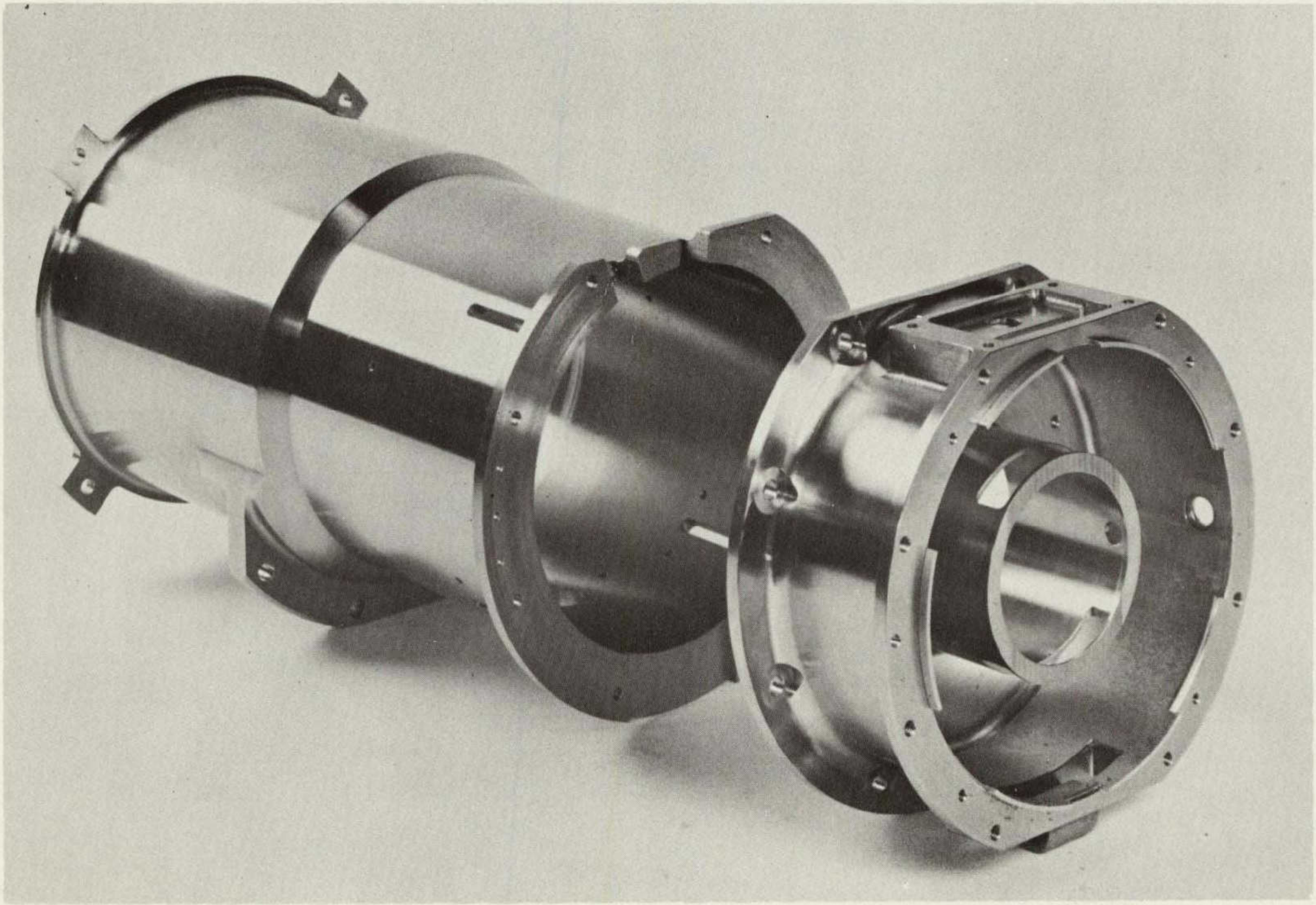


Figure II-15. Lens Mount (shown with Front Focus Coil Housing)

The lens is installed into the lens mount by means of a single intermediate aluminum sleeve separating the titanium lens barrel from the titanium lens mount. The bearing surface of the aluminum sleeve has an antifriction Hardcoat finish. Concentricity and dimensional tolerance are tightly controlled.

The lens is held axially by the four aluminum (7075-T6) thermal rods which are totally enclosed within the lens mount.

The lens mount is supported by means of a front foot which is bolted to a flange located beneath the lens mount. The lens within its mount is essentially cantilevered forward of the front foot.

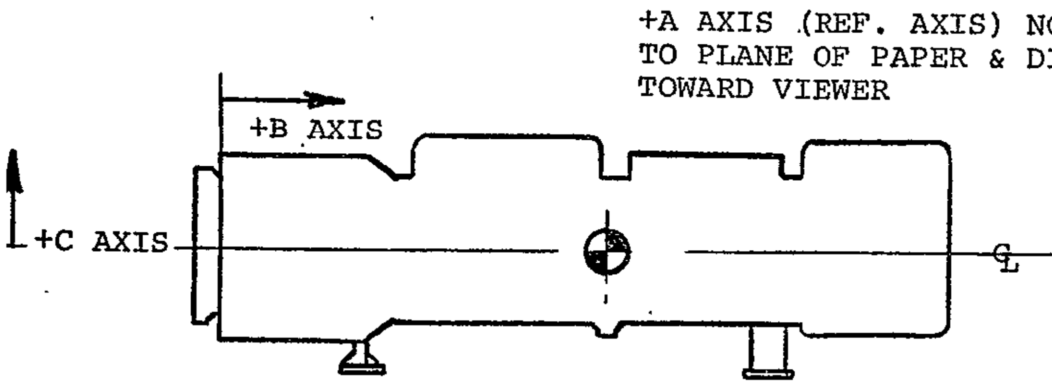
- <u>Thermal Compensation Mechanism</u> - The camera has the capability to maintain optical focus over a $40^{\circ}C$ range from $5^{\circ}C$ to $45^{\circ}C$. A thermal compensation mechanism is used consisting of four aluminum thermal rods fixed in position near the front focus coil housing, which are free to expand and contract with changes in temperature. This small change in thermal rod length maintains the athermalization of the lens by moving the lens sleeve, to which the lens is bolted, closer or further away with respect to the vidicon.

  Care was taken in the design of the lens to allow achievement of athermalization with a common alloy over a range in thermal rod length of not greater than five-inches. To this extent, a specification value on lens variation in flange focal distance of 0.00027 ± 0.00010 cm/$^{\circ}C$ was used. This specification limit was achieved by the lens vendor with a typical lens having a variation of 0.00030 cm/$^{\circ}C$ in vacuum.

- Performance Capability - The camera was qualified for launch vibration for both sinusoidal and random vibration based on the known levels that would be transmitted to each camera. These levels of test are shown in Tables II-10 and II-11.

- Mass Properties - The center of mass was calculated and later verified by measurement to be as follows:

Center of Mass



A = +0.068 IN.   B = +11.532   C = -0.031

Mass Moments of Inertia

I_{A-A} = 2386 lb-in^2

I_{B-B} = 75 lb-in^2

I_{C-C} = 2364 lb-in^2

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The camera weight is 47.74 pounds, 8.8 pounds heavier than the Landsat 1&2 type cameras.

TABLE II-10. DQM CAMERA/BASEPLATE - RANDOM QUALIFICATION VIBRATION (ALL AXES)

Frequency (Hz)	PSD Level (g^2/Hz)	Acceleration (g-RMS)	Duration
20	0.0023		2 Min
20 - 300	*	12.8	Ea. Axis
300 - 2000	0.09		
* Increasing from 20 Hz at a rate of 4 dB/Oct. to .09 g^2/Hz at 300 Hz.			

2. RBV Baseplate Assembly

The Landsat-C camera mounting baseplate has the same mounting interface as the previous system. The baseplate thus was limited to minor design changes and then only to accommodate two cameras as opposed to three for the earlier systems.

- Structure
  The baseplate was made slightly longer to accommodate the increased camera length, and slightly narrower since this is a two camera system. The baseplate is an aluminum alloy casting, type 356 T-6, and uses the identical isolator mounts as Landsat 1 & 2 for mounting to the spacecraft. The overall height of the baseplate was reduced 0.25-inch for camera clearance within the spacecraft. Each camera is mounted on 4 pads which are cast into the baseplate and machined to the proper critical elevation and azimuth angles.

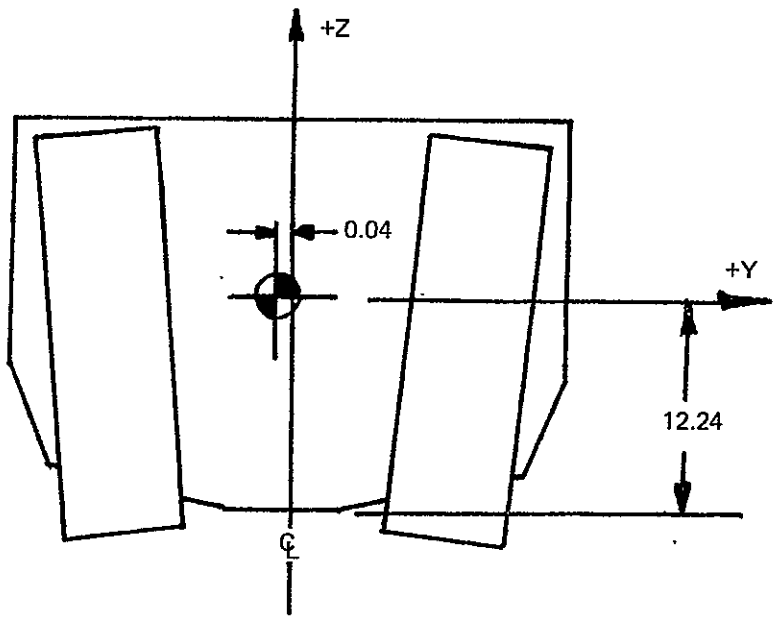
TABLE II-11. DQM CAMERA/BASEPLATE - QUALIFICATION VIBRATION, SINUSOIDAL

Axis	Frequency (Hz)	Acceleration (g) (0 to Peak)	Sweep Rate
X	5 - 30	3.8*	2 Octaves /minute
	30 - 50	7.5	
	50 - 150	5.0	
	150 - 175	3.5	
	175 - 250	1.8	
	250 - 400	3.5	
	400 - 1400	5.0	
	1400 - 1800	3.0	
	1800 - 2000	5.0	
Y	5 - 30	3.8*	
	30 - 50	7.5	
	50 - 95	5.0	
	95 - 140	3.5	
	140 - 270	5.0	
	270 - 370	1.8	
	370 - 1600	5.0	
	1600 - 2000	2.0	
Z	5 - 50	6.0*	
	50 - 90	11.0	
	90 - 100	5.0	
	100 - 160	2.5	
	160 - 320	3.0	
	320 - 2000	5.0	

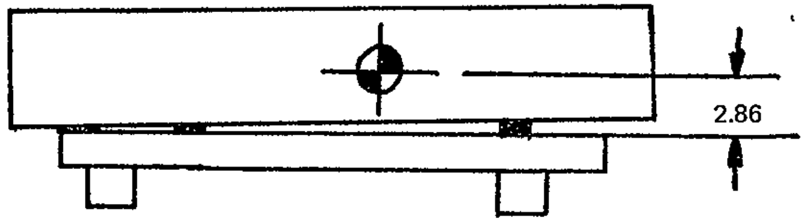
*Exposure limited to 0.50 in. D.A.

- Performance - The baseplate, with two cameras in place, met the same qualification requirements for vibration as did the cameras. The baseplate, which weighs 29.5 pounds with radiator and isolator mounts exhibits the following mass properties when two cameras are mounted:

Center of Mass (Two Camera System)



(THE +X AXIS IS DIRECTED TOWARD THE VIEWER)



Moments of Inertia

I_{XX} = 16,598 lb-in^2

I_{YY} = 6,319 lb-in^2

I_{ZZ} = 5,294 lb-in^2

I_{XY} = -

I_{ZX} = 105 lb-in^2

I_{YZ} = -

Focus and optical alignment were not effected by vibration.

F. ELECTRICAL PERFORMANCE

1. Camera Controller Combiner (CCC)

The basic requirements of the Landsat-C Camera Controller and combiner (CCC) are listed below. Specific changes from the previous CCC design used in the three camera RBV subsystems are noted in the following section.

(a) Command Decoding - The CCC is required to accept certain of the spacecraft commands and provide necessary responses, memory or routing, as required to properly control the operation of the two camera RBV subsystem.

(b) Timing and Mode Control - The CCC is required to serve as the master timing generator for all of the intermediate functions performed within the subsystem. This includes generating timing signals for use by the camera deflection generators, camera control circuits, internal CCC functions, and other spacecraft subsystems (e.g., the Time Code Processor). Control of the various modes of the subsystem operations is accomplished by the CCC in response to commands processed by the command decoder.

(c) Video Processing - The CCC is required to generate the composite video signal output from the two individual camera systems. This includes inserting vertical sync, horizontal blanking, calibration, camera identification, and time code signals in the composite video data.

(d) Power Conditioning - The CCC is required to convert regulated -24.5V spacecraft input power, into +6 volts for use by the CCC logic circuitry and ±15 and -5.25 volts for use by the analog circuitry within the CCC.

(e) Telemetry - The CCC is required to provide telemetry outputs for monitoring subsystem performance and operation, for fault diagnosis, and for command acceptance verification.

Table II-12 lists the changes between the three-camera and the two-camera systems that affect the CCC. In addition to these system changes, the logic hardware was changed from low power DTL (and some TTL added in revisions to the original design) to low power TTL 54L series logic. These changes affected the seven digital boards within the controller section of the CCC, resulting in new logic designs and board layouts. Changes to the remaining six CCC boards involved only parts upgrading, cleanup of previous ECN's, and deletion of the camera 3 circuitry. Table II-13 summarizes the changes made to each board within the CCC.

TABLE II-12. CCC CHANGES FROM THREE-CAMERA DESIGN

THREE-CAMERA SYSTEM	TWO-CAMERA SYSTEM
• 25 SEC CYCLE TIME	• 12.5 SEC CYCLE TIME
• ΔOB = 2.0 SEC	• ΔOB = 1.5 SEC
• SIMULTANEOUS ERASE, PREPARE, EXPOSURE	• STAGGERED ERASE, PREPARE, EXPOSURE
• 14.5 SEC ERASE/PREPARE INTERVAL	• 9.0 SEC ERASE, PREPARE, EXPOSURE
• VTR'S CYCLED ON/OFF BY CCC	• VTR'S RUNNING CONTINUOUSLY AND NOT CONTROLLED BY CCC
• SHUTTER SPEEDS 4, 4.8, 5.6, 6.4, 8, 8.8, 12 AND 16 MSEC	• SHUTTER SPEEDS 2.4, 4, 5.6, 8, AND 12 MSEC
• TIME CODE UPDATE 2.5 SECONDS PRIOR TO BEGINNING OF READ 1	• TIME CODE UPDATE 1.0 OR 1.5 SECONDS (MOVING WINDOW) PRIOR TO BEGINNING OF READ 1
• VTR REPHASE 3 SEC PRIOR TO BEGINNING OF READ 1	• VTR REPHASE 1 SEC PRIOR TO BEGINNING OF READ 1

CCC Circuit Board	Functional Grouping	Board Components	Description of Changes
A1, A3, A4, A5 A6, A7, A8	Logic and Interface Circuits	54L TTL IC's + discrete components	Completely new design and board layout
A2	Command Decoding	TO-5 Can relays and diodes	No changes (except parts upgrading)
A9	Harness Board	MALCO 60 or 86 pin connectors	Some minor changes to PC traces and discrete wiring
A10, A11, A12	Video Analog Circuits	Discrete components + a few IC OP AMPS	Clean-up of previous ECN's and parts up-grading
A13 Assy (Consists of 2 boards)	DC/DC Converter	Discrete components + a few IC voltage regulators	Clean-up of previous ECN's and parts up-grading

Six of the seven digital circuit boards were designed to be assembled by a buttonhead weld process (one board with a low IC count used conventional assembly method). A buttonhead welded assembly is an electronic circuit board on which the parts are attached by parallel gap welding or soldering to terminals which have been press fitted into a two-sided printed circuit board. Electrical interconnection between terminals is made by welding through the Teflon insulation of a continuously running nickel wire for all electrically common points. Connectors, power and ground connections and certain other parts which do not adapt to standardized patterns are connected to weld terminals, using conventional printed-wiring techniques. In-process welding is controlled by frequent weld sample destructive evaluation.

Figure II-16 is a block diagram of the CCC indicating major sections of the CCC and their interfaces. The section of the CCC that was primarily affected by the system changes and the DTL to TTL conversion was the Timing and Mode Controller.

The timing diagram, Figure II-17 shows the relationship between Camera 1, Camera 2, and Output Data Format timing. The CCC/Spacecrai digital interfaces are summarized in Table II-14.

Further details of the CCC design may be found in Section VI of the RBV Critical Design Review submission dated November 6, 1975, (Ref. VII C3).

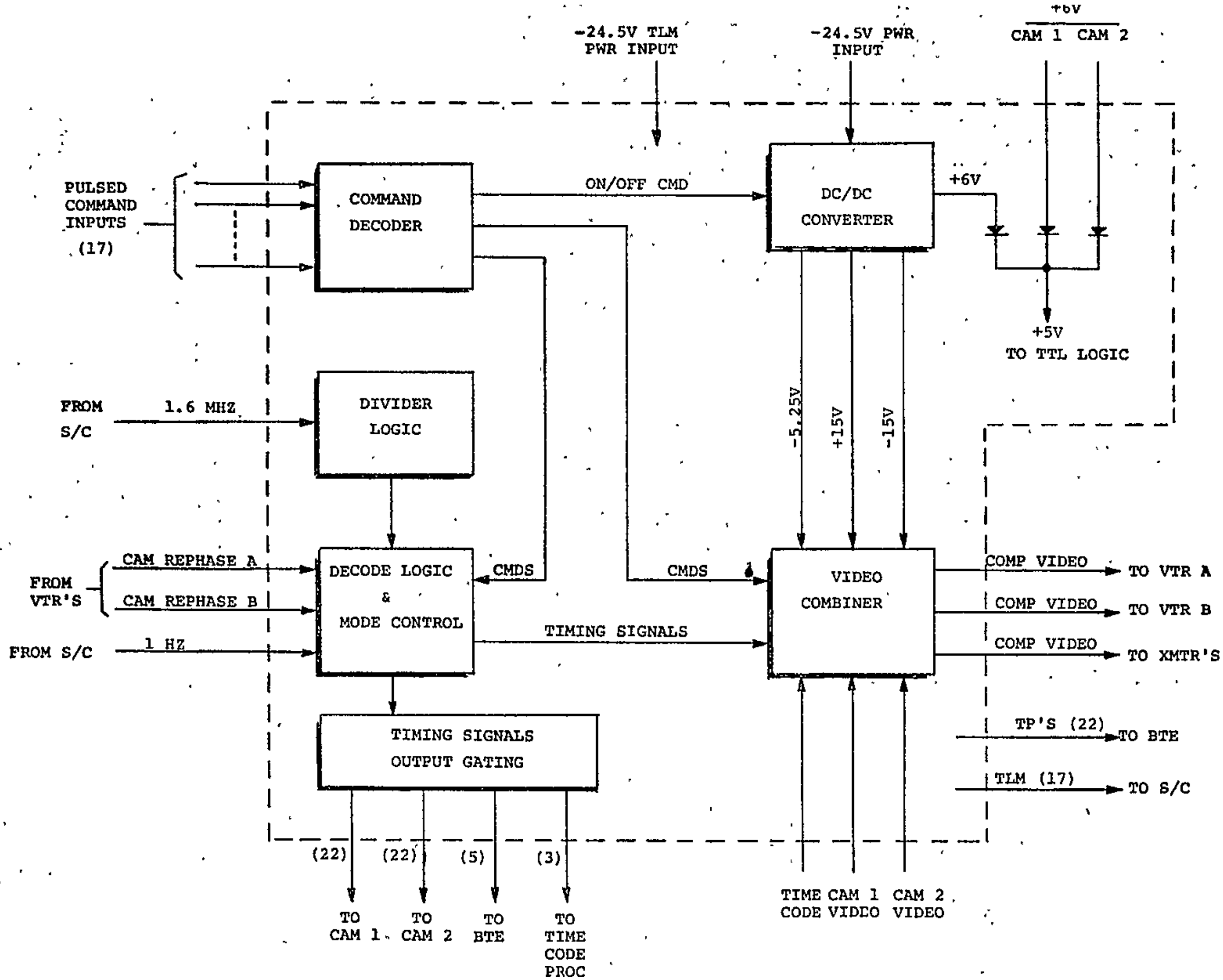


Figure II-16. Camera Controller and Combiner Block Diagram

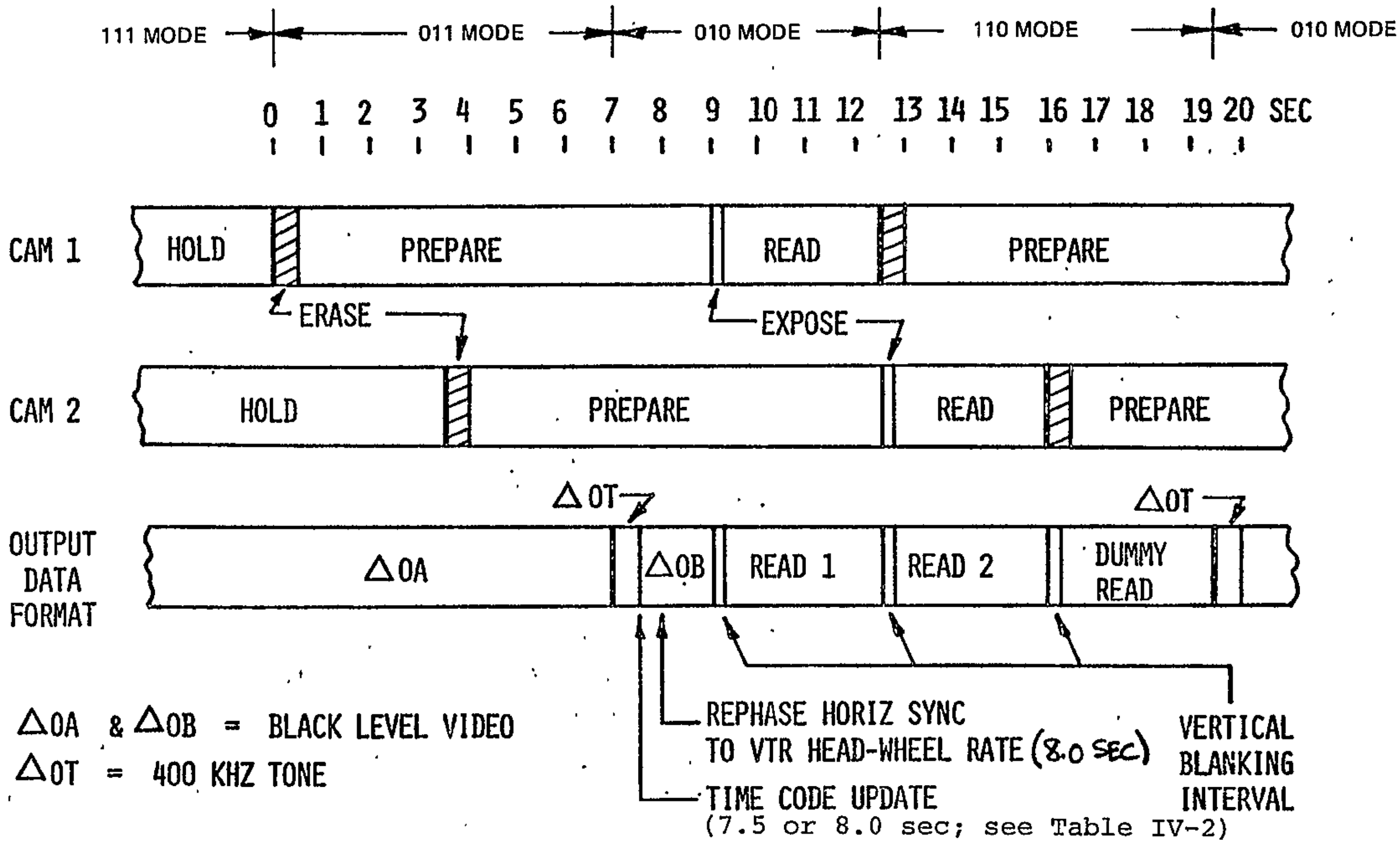


Figure II-17. Camera and CCC Output Data Timing

TABLE II-14. CCC/SPACECRAFT DIGITAL INTERFACES

<u>SPACECRAFT TO CCC</u> • 1.6 MHZ CLOCK • 1 HZ CLOCK • 312.5 HZ REPHASING SIGNAL #1 • 312.5 HZ REPHASING SIGNAL #2	INTERFACE UNCHANGED FROM PREVIOUS 3-CAMERA DESIGN
<u>CCC TO SPACECRAFT</u> • TIME CODE UPDATE (WAS T_O + 12 SEC) • TIME CODE SYNC • TIME CODE ENABLE	INTERFACE CHANGED FROM DTL BUFFER GATE (9930) TO TTL MEDIUM POWER INVERTER (5404)

2. Shading Correction

Two modifications have been made to the RBV system to reduce the shading components of the output video. The first modification is the design of a new shading correction circuitry which reduces the shading components remaining in the video output. The shading correction circuitry is located in the Camera Electronics. Correction is made by (1) changing the gain of the video signal as a function of scan beam position to reduce sensitivity variations, and (2) changing the dc level of the video output to compensate for changes in the baseline amplitude.

The second modification is the addition of an exponential waveform to the target voltage in order to compensate for the transients occurring in the photoconductor caused by the non-uniform depth of the dielectric layer of the vidicon. The modification consists of the addition of an exponential waveform generator to the Target Voltage Control in the sensor. The exponential waveform is summed with a linear vertical ramp and the composite correction signal is subtracted from the target voltage during read.

a. Shading Corrector Circuit

This paragraph will explain the two components of shading, show the techniques used in the previous shading corrector, detail the new approach, and give a detailed circuit description of the new design.

The clamped video from the preamp contains two components of shading. Baseline or black level shading is defined as amplitude changes in the signal when no light is impressed on the vidicon. It can be thought of as a change in level of the baseline voltage. Sensitivity or white level shading is defined

as the change in gain of the vidicon. This change is usually measured at peak white amplitude.

Baseline shading correction is accomplished by adding a correction voltage to the video output. The correction voltage must be a predetermined complex function of the position of the reading beam. Previous correction techniques provided a baseline correction voltage Vc as shown below.

$$Vc(t) = a\left(\pm Vx(t)^2 \pm b\ Vx(t)\right)$$
$$\pm c\left(Vy(t)^2 \pm d\ Vy(t)\right)$$

where: $Vx(t)$ is the horizontal linear ramp

$Vy(t)$ is the vertical linear ramp

$Vx(t)^2$ is a horizontal parabolic

$Vy(t)^2$ is a vertical parabolic

The correction waveform provides fairly good correction except at the top, bottom and the extreme corners of the readout.

The new baseline correction voltage allows the horizontal correction amplitude to change as a function of the vertical position. This is accomplished by forming a cross product term between the horizontal and vertical terms. The complete correction voltage function becomes

$$Vc(t) = \pm a\ Vx(t)^2 \pm b\ Vx(t) +$$
$$\pm c\ Vy(t)^2 \pm d\ Vy(t) +$$
$$i\left(\pm e\ Vx(t)^2 \pm f\ Vx(t)\right) \cdot \left(\pm g\ Vy(t)^2 \pm h\ Vy(t)\right).$$

Note that the first two terms of the sum are equivalent to that of the previous correction function, while the third term, the cross product term, is new. We can think of the vertical part of the third term as a slowly changing function modulating the gain of the higher frequency horizontal term. The coefficients a through i represent gain value predetermined by potentiometers.

Sensitivity shading correction is accomplished by modulating the video signal amplitude as a function of the applied correction voltage. The correction function is the same as that for baseline correction but all coefficients a-i are independently adjustable. The correction voltage is applied to a modulator which forms the shunt resistor in a shunt modulator. The shunt resistance is a function of the correction voltage. The modulator is referenced to the baseline level so that only the gain, not the baseline level is affected by the modulator.

1. Circuit Description

The following paragraphs summarize operation of the shading correction circuitry. A block diagram of the Shading Corrector is shown in Figure II-18.

2. Horizontal Function Generator

The Horizontal Function Generator generates horizontal linear ramps and horizontal parabolas of both positive and negative polarities. The input to the generators is obtained from sampling the current which passes through the horizontal deflection coils.

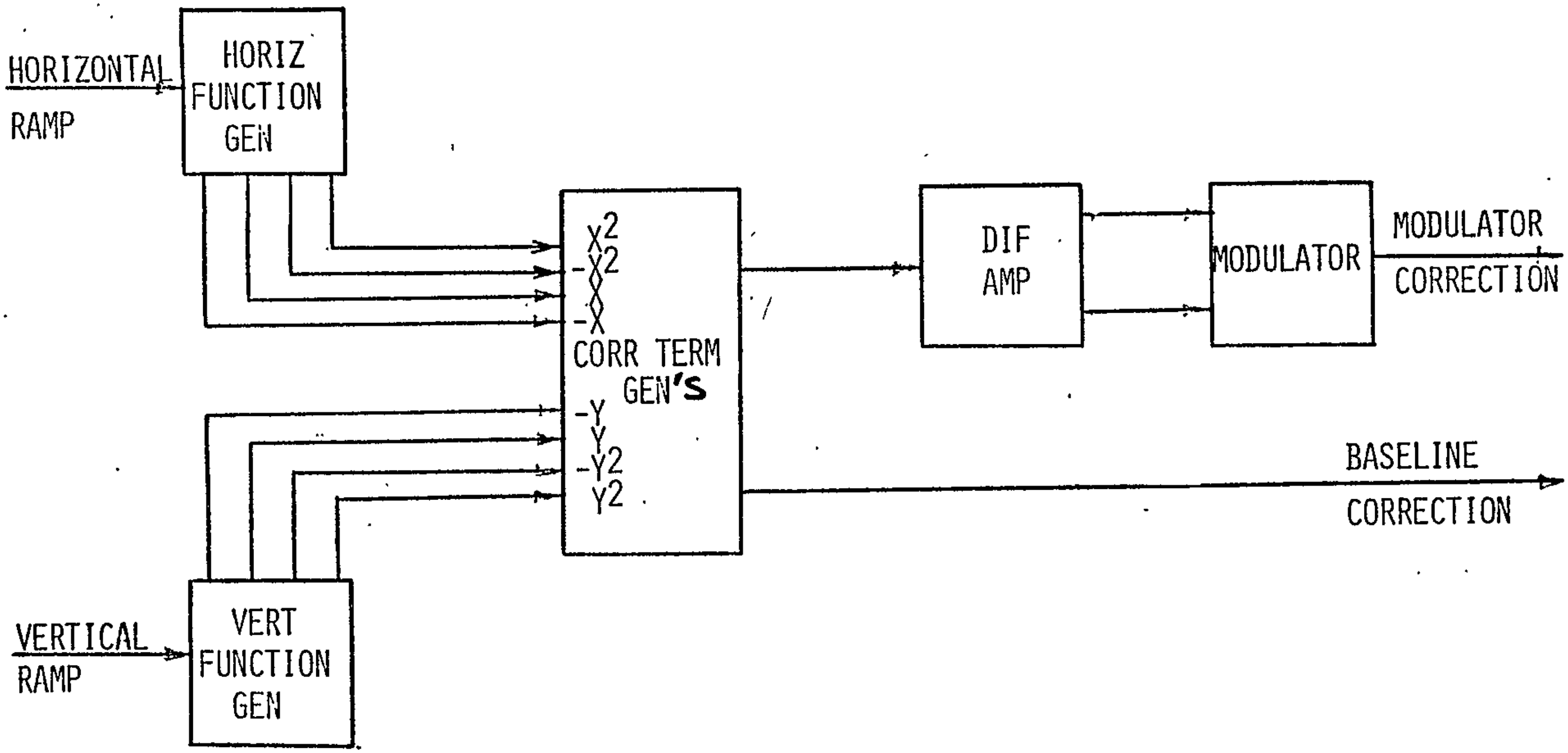


Figure II-18. Shading Corrector Block Diagram

3. Vertical Function Generator

The vertical Function Generator converts the vertical ramp input obtained from the vertical deflection current sample into linear vertical ramps and vertical parabolas of both polarities. It is functionally the same as the horizontal function generator.

4. Sensitivity Correction Term Generator

The Sensitivity Correction Term Generator inputs the X, -X, X^2, and $-X^2$ horizontal outputs from the Horizontal Function Generator and the Y, -Y, Y^2, and $-Y^2$ vertical outputs from the Vertical Function Generator, combines these terms, and conditions the signal such that it is compatible with the differential amplifier which drives the modulator.

The amount and polarity of horizontal ramp correction is determined by a potentiometer setting. At the center of the potentiometer the correction is zero since the X and -X signals are of equal but opposit polarity. The amount and polarity of horizontal parabolic correction is also determined by a potentiometer setting. The two horizontal terms are then summed in an amplifier.

Similarly, the vertical summing amplifier accepts the vertical ramp signal and the vertical parabola signal.

The third sensitivity term is a cross product term formed by a differential multiplier. The input horizontal ramp, the parabolic terms and the vertical terms are selected by potentiometers, summed in an amplifier and fed to the differential amplifier.

5. Differential Amplifier and Modulator

The Differential Amplifier and Modulator essentially remain unchanged from the earlier camera design. The only exception is that the combined sensitivity term is now fed to the base of one transistor of the differential amplifier while in the previous design the vertical and horizontal terms were fed to opposite transistor bases.

6. Baseline Correction Term Generator

The Baseline Correction Generator is similar to the Sensitivity Correction Term Generator with the exception that the horizontal, vertical, and cross product terms are not summed in an amplifier, but each is summed into the video signal.

7. Detailed Analysis

A detailed analysis of the Landsat C/RBV Shading Correction Circuit design is contained in the Critical Design Review Package (Reference VII C3).

G. LENS SPECIFICATIONS

1. Lens Description

The Landsat-C/RBV lens is a nominal 236 mm f/2.9 lens covering the 25.4 mm square image format of the two-inch, return-beam vidicon. The ten element lens includes a 9.5 mm thich quartz window as the first element for radiation protection and a plano-plano absorption filter (7th element) which acts as a haze filter, cutting off short wavelength radiation. The elements are housed in a titanium lens barrel. The lens thermal design is such as to permit athermalization of camera performance with a relatively simple mechanical design. The lens was designed to RCA performance specifications by the Fecker Systems Division of the Contraves-Goerz Corporation, Pittsburgh, Pennsylvania. A cross-section of the lens is shown in Figure II-19.

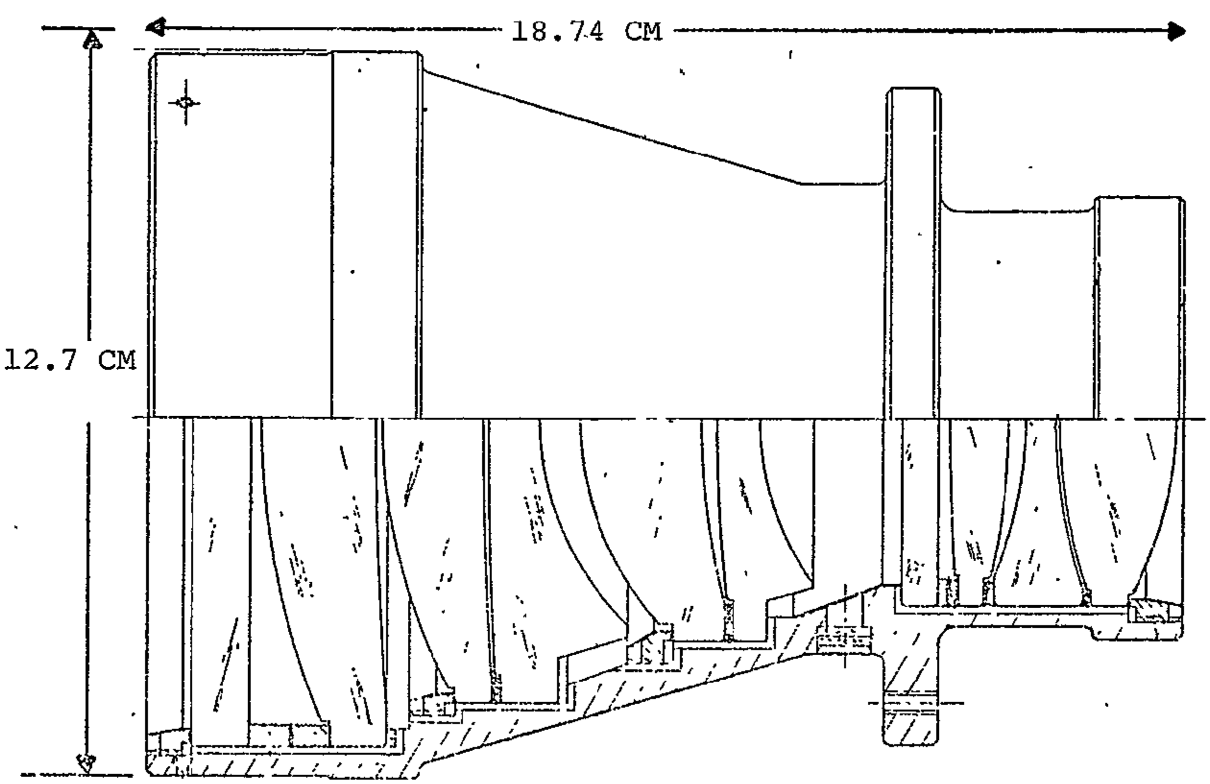


Figure II-19. Lens Cross-Section

2. Lens Design

The focal length of 236 mm will produce a nominal image of a 53 nautical miles square area of the earth within the 25.4 mm square raster of the vidicon from an orbital altitude of 492 nautical miles, as required by the system specification. The lens focal length has a specified tolerance of 0.5% and is measured to an accuracy better than 0.2%.

The lens specified T/number, 3.3, in conjunction with a design f/number of 2.9 means that lens transmission must be a minimum of 77%. Actual transmission exceeds 77% and was achieved by the use of multilayer antireflection coatings, glass selection, and control of internal reflections.

The choice of lens f/number was based on tradeoff considerations involving size, weight, relative illumination, and imaging performance. In particular, two physical constraints in the basic mechanical design of the camera are of major significance. The first of these is the existence of a limiting aperture, the vidicon faceplate thermal control unit, 35 mm in diameter and located 46 mm in front of the faceplate. This limiting aperture introduces vignetting. Compensation for this vignetting is achieved partially by the lens design (forcing the entrance pupil as close to the faceplate as practical) and by shading correction electronic circuits. Shifting the entrance pupil close to the faceplate increases the diameter of the front lens elements. In addition to increasing weight, this process is limited by the second physical constraint, which is the distance between the optical axis and the camera mount (baseplate). The achievable MTF, which is ultimately limited by f/number, is high enough to provide adequate margin for meeting the specified limiting resolution of 4500 TV lines and provide low-contrast target resolution somewhat in excess of that obtainable in the channel 2 camera of Landsat 1 and 2.

The lens MTF (sine wave) minimum values are specified 55% at 90 lp/mm within a 21.3 mm circle in the image plane, and 45% at 72 lp/mm in the remainder of the format.

Distortion was specified to be less than 0.05 mm which is one-fifth of the total system allowance.

Particular attention has been paid in the lens design to minimize veiling glare. In an operational situation, it will not be unusual for large areas of the earth to be covered by clouds having radiances as great as five times specified highlight radiance. In such a case, and particularly in a scene containing low reflectances from the earth's surface, veiling glare can reduce limiting resolution significantly. Veiling glare has been specified ($\leq$ 3%) to be as small as can be expected when all reasonable measures to reduce it have been taken.

3. Criteria for Selection of the Spectral Bandwidth

The effects of new spectral response data from vidicon tubes showed a shift of response to longer wavelengths when compared to the response characteristics used in previous studies. The effect of this data on system performance was studied using the average spectral response of the first seven tubes measured. (Measurements on remaining tubes showed similar spectral response characteristics to that of the first seven). Computer processing of the old and new data was used to aid in selection of the shortwave cutoff filter.

The limiting resolution was studied as a function of the wavelength at which the short wavelength cutoff filter has a transmission of 50%. An f/number of 3.0 (T/3.4) was used for all cases as was a constant integrated exposure equal to that which would be obtained in Channel 2 of the three camera RBV (Landsat 1&2) system. Normal viewing conditions were

used; i.e., normal visibility of 23 kilometers, and a solar zenith of 49°. Average resolution consisted of one-half of the total of vertical resolution plus horizontal resolution under normal viewing conditions.

In all cases studied using the old tube spectral response data, and then the new tube spectral response data, the average limiting resolution increased noticeably as filter cutoff wavelength is reduced from 550 to 510 nanometers.

When the viewing conditions were reduced to a visibility of 10 kilometers at a solar zenith angle of 80° the effects were similar to those previously noted. Variation of average limiting resolution is not appreciably changed.

Variations of average limiting resolution as a function of filter cutoff wavelength is shown in Figure II-20 for twelve different target combinations. For the most part, differences in the variation of limiting resolution due to the change in tube spectral response are small. In each curve, decreasing the filter cutoff from 550 to 510 nanometers results in improved resolution for eleven of the twelve cases. The conclusion was to change the original specified cutoff frequency of 550 nm to a sharp cutoff at approximately 505 nm. This was achieved by the use of the Schott filter designated GG495.

The weightings used for MTF calculations based on a combined lens-filter-vidicon response were:

λ (nm)	500	540	580	620	660	700
Weighting	0.30	0.90	1.00	0.78	0.39	0.13

Subsequent direct measurements of vidicon spectral response indicate the average peak response is approximately 600 nm and the red region extends to approximately 820 nm. The effect of this

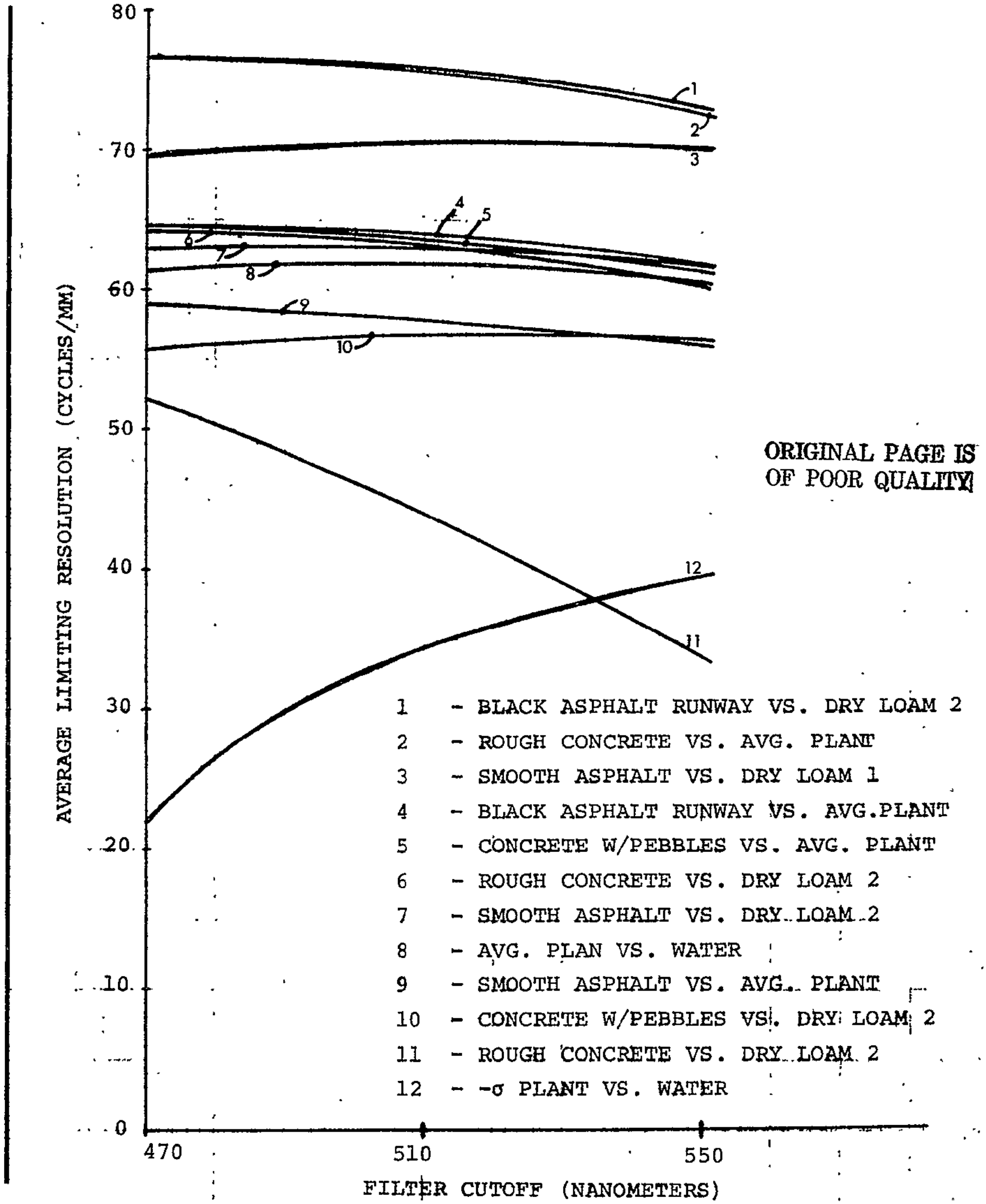


Figure II-20. Variations of Average Limiting Resolution for Different Target Combinations

difference is a decrease in lens calculated MTF by approximately 7%. (The effect on system MTF is less).

4. Lens Performance

Performance data for each of the four lenses built for the Landsat-C/RBV camera program are summarized in Table II-15. Serial number one (01) was the prototype lens and has the same form, fit and function as the flight lenses. (A vibration model lens was built to evaluate the mechanical design of the lens under the qualification level vibration). The prototype lens also received qualification level vibration. The lenses used in Flight Cameras were vibrated at flight levels prior to installation in the cameras.

TABLE II-15. LENS PERFORMANCE

LANDSAT-C LENS PERFORMANCE FOR TWO-INCH RETURN BEAM VIDICON CAMERA SYSTEM								
Parameter	Prototype S/N - 01		S/N - 02		S/N - 03		S/N - 04	
Focal Length (Vacuum) Field of View (Diagonal)*	235.68 mm 8.716°		235.60 mm 8.719°		235.32 mm 8.748°		235.47 mm 8.724°	
Focal Length (Air)	235.86 mm		235.78 mm		235.50 mm		235.65 mm	
T/number	3.3		2.970		3.008		3.056	
Veiling Glare	1.77%		1.18%		1.73%		1.12%	
Distortion (Radial) max.	+0.020 mm		-0.020 mm		-0.023 mm		-0.024 mm	
Distortion (Tangential) max	+0.008 mm		+0.006 mm		+0.007 mm		-0.008 mm	
MTF (Post-Vibration, Post-Thermal, 25°C Ambient, On-Axis)								
	R	T	R	T	R	T	R	T
0 Cycles/mm	100%	100%	100%	100%	100%	100%	100%	100%
25	n/a	n/a	93.0%	89.0%	91.0%	90.0%	91.0%	93.0%
50	n/a	n/a	83.0%	75.0%	79.0%	77.0%	81.0%	84.0%
72	n/a	n/a	73.0%	66.0%	68.0%	66.0%	72.0%	74.5%
90	63.5%	61%	64.0%	58.0%	58.0%	56.0%	63.5%	67.0%
Spectral Transmission	Refer to Spectral Transmission Curve (Figure II-21)							
Relative Illumination	Refer to Illumination Contour Plot (Figure II-22)							
Thermal Operating Range	Operational Capability 5°C to 45°C							
Vibration Capability								
Sinusoidal	5 - 2000 Hz, maximum 35-g (200-500 Hz Region)							
Random	20 - 2000 Hz, 12.6-g_{rms} (three minute duration)							
* - Single Camera Ground Coverage (494 nmi. orbit)	53.241 nmi Square		53.259 nmi Square		53.437 nmi Square		53.289 nmi Square	
Weight	4540 gm		4567.2 gm		4576.3 gm		4568.4 gm	

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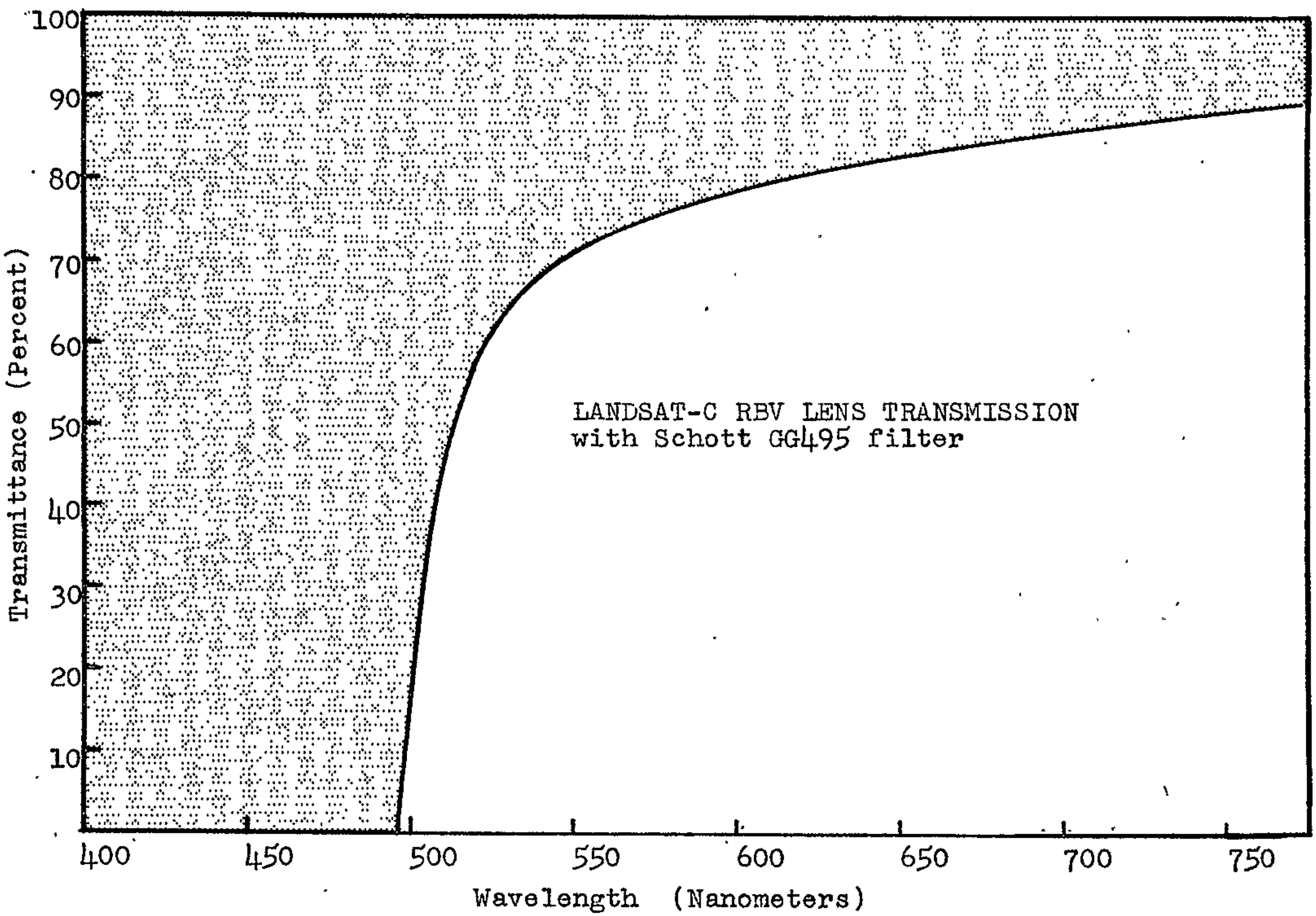

Figure II-21. LANDSAT-C RBV LENS TRANSMISSION
with Schott GG495 filter

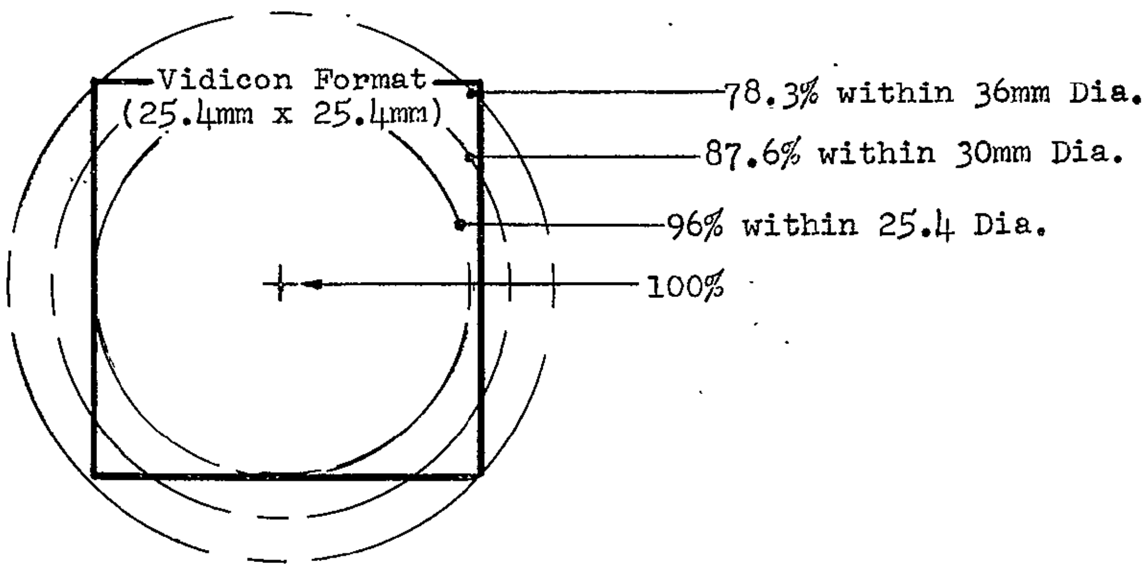

Figure II-22. Relative Illumination (Average of 3 Lenses)

H. VIDICON SELECTION CRITERIA

The vidicons for the Landsat C program were obtained from the NASA residual inventory of return-beam vidicons which were were purchased for Landsat 1&2. Thirteen of the residual two-inch RBV's were selected for periodic exercise and test. The RBV requirement for Landsat-C consists of vidicons for two flight-model cameras and a spare flight-qualified camera with the additional requirement of a spare flight-qualifiable vidicon, a total of four. The qualification model had a vidicon assigned to it already since it too is residual inventory from Landsat 1&2.

The objective of the vidicon selection portion of the program was to evaluate the 13 vidicons and make a selection of the four required.

1. Method of Use in the Camera

As indicated elsewhere in the report, the Landsat-C/RBV is used in a mapping application. The two flight cameras are arranged to take nearly simultaneous pictures of adjacent areas so that pictures from the two cameras, with approximately a 53 nautical mile field-of-view, may make a sequence of 98.5-mile wide map segments as the satellite travels along its orbit. Since each sequence of pictures is arranged to be contiquous along the orbit, a resulting map of a 98.5-mile wide strip is made. This is described in greater detail elsewhere in this report, however, the following paragraphs describe the process as it involves camera operation.

As indicated previously, the picture-taking sequence of each camera requires 12.5 seconds, and the sequence of Camera No.2 is delayed with respect to that of Camera No.1 by 3.5 seconds so that sequential video readout can be provided. Each camera requires four cycles of operation during each picture-taking operation: Erase; Prepare; Exposure; and Readout.

The erase cycle is used to remove any information which may have been stored on the vidicon photoconductor. Erase is accomplished by optically discharging the photoconductor, using small lamps; the lamps are energized for one-half second during the erase cycle.

The prepare cycle, which follows the erase cycle, is used to charge the surface of the photoconductor to a predetermined

potential. This is accomplished by scanning the electron beam across the photoconductor surface a sufficient number of times. The prepare scan is a 3.125 kHz triangular beam. Each prepare frame lasts one-half second; thereby, providing 3125 scan lines. The prepare cycle is 8.5 seconds, which provides 16 frames (8.0 seconds) of prepare followed by a final 0.5 second interval for switching the vidicon electrode voltages. During this final interval the beam is blanked off.

During the expose cycle, which occurs during the vertical blanking time (between the 0.5 second interval and camera readout), the photoconductor is exposed to the desired image for a nominal 5.6 millisecond period by means of a focal plane shutter.

Readout of each camera follows its corresponding exposure and lasts 3.5 seconds. Since readout of the two cameras is sequential, exposure of Camera 2 occurs 3.5 seconds after that of Camera 1. The scan rate during readout is 1250 lines per second, thereby providing a total of 4375 (4125 active) scan lines during one Read frame. The resulting video signal will be transmitted directly or stored on a video tape recorder as required.

2. Test Program

Vidicons were selected on the basis of their picture-making qualifications, and upon electrical measurements indicating gun and target performances. Picture quality criteria are of an esthetic nature and depend on subjective observation; it may vary from observer to observer, but while somewhat variable, it

remains of prime importance. The electrical tests verify gun construction quality, assure cathode performance and reliability, and measure performance of the target semi-conductor.

A series of tests were conducted at approximately 3-month intervals. This involved exercising of the vidicon by reproducing a test cycle which is similar to the cycling experienced by the vidicon in orbit. After an exercise period the vidicons were tested and the data compared to that of previous tests. In some cases the cathode performance may have deteriorated, and further exercising was carried out. This consists of adjusting the electrode voltage for "prepare" operation and cycling on and off for extended periods. If the vidicon cathode recovered satisfactorily, electrical and picture quality tests were carried out. Some of the tubes required only a short cycling period and others extended exercise periods to bring about a full recovery. This requirement for a reactivation period, while not desirable, at the same time is not considered detrimental to the quality rating of the tube. It is simply a chemical-physical activation process which requires more time with some cathodes. Usually the cathode recovers and does not require further activation on successive exercise periods. Some vidicons which continued to require activation were reduced to a category of lower acceptability. The tests made at each exercise period included the following measurements:

Grid cut-off voltage for $I_K = 1\ \mu a$

Cathode current during prepare

Cathode current during read
Target voltage during prepare
Target voltage during read
Beam current when cathode current = 2 mA
Signal-to-noise ratio using channel 2 light and white light
Cathode leakage current
Peak signal output
Total signal current
Return-beam modulation
Multiplier gain
MTF using channel 2 light
MTF using white light
Horizontal signal and black shading
Vertical signal and black shading

In addition, cosmetic picture quality criteria were noted, such as the number and size of spots and blemishes and smears.

As the vidicons were exercised and examined at successive periods the data was sampled to look for any significant changes occurring as a function of time. A change of data values might predict deterioration which would show up during the periods of assembly, test, and usage of the complete camera system.

As the selection process continued and flight and spare candidates were selected, more exhaustive tests were conducted prior to environmental testing of the camera. This included recording of monitor and waveform pictures.

3. Mapping of Reticles

After the flight and spare vidicons had been selected, their reticles were accurately mapped. This data is required inasmuch as the Landsat-C Camera will be used for mapping, and a size reduction of approximately 4.248×10^6 to 1 is carried out in photographing the earth. Hence a very slight error in reticle placement on the face plate could produce significant mapping errors. To accomplish this the vidicons were taken to

the laboratories of U.S.G.S. Reston, Va. where the location measurements of each reticle were made on precision measuring equipment. The results of these mapping calibrations are printed in Appendix A (Section III) of this report.

4. Spectral Response Measurements

Each of the 13 flight candidate vidicons was measured to confirm its spectral response. This measurement was made with the RBV operating normally in a laboratory camera. A monochromator was used to project light on a patch on the vidicon's face plate. The lamp in the monochromator, appearing through a 0.5 mm slit was adjusted to provide a vidicon output which is $\frac{1}{3}$ of full scale, black-to-white amplitude when a shuttered exposure was supplied. An "A" scope presentation including 10 or 12 scanning lines was photographed with a Polaroid camera. This was repeated for various wavelengths of light in 20 nm steps until readings each side of peak response was reduced to about 5% of maximum. This data was repeated for a full scale vidicon output reading.

5. Environmental Testing

Each selected vidicon was environmentally tested at levels in accordance with its planned ultimate usage. The testing includes a vacuum test to check the potting material which encloses the tube base wiring for dielectric breakdown.

The vidicon was placed in a fixture after having been given a thorough pre-environmental test of electrical properties and after the potential picture-taking quality was noted. It then was subjected to vibration testing, after which it was submitted to a post-vibration test to ascertain if any changes occured as a result of vibration.

In summary the prototype vibration levels are: sine wave up to ±30 g peak, and random up to 22 g's RMS. The Flight Acceptance Tests (non-operating) call for: up to ±15 g peak sine wave, and up to 11 g RMS for random vibration.

6. Vidicon Life Test

While the previous performance in the test and flight operation of Landsat A and B have provided confidence in the life expectancy of the RBV Vidicons, it was considered desirable to verify this data on a sample of the present stock of tubes. To statistically acquire life expectancy data requires extensive testing on a large number of units. The life test was started on October 20, 1975 on RBV #S19943 and concluded on March 9, 1976.

This vidicon had previously experienced 134 hours of test time at the start of the life test program. The parameters of principal interest which were periodically monitored are shown in Table II-16.

The test was set up to cycle the vidicon on for 20 minutes and off for 10 minutes. (In orbital operation, the OFF time is 80 minutes).

During the 20 minute active period the vidicon was under "prepare" conditions for 8 seconds, and then with beam off for 3.5 seconds, followed by 3.5 seconds under "read" conditions.

The electrode voltages were set up in accordance with Landsat-C "prepare" and "read" conditions and held at these values throughout the test.

At the end of 303 hours (active "on" time = 201 hrs.) the vidicon was retested, and then retested at approximately 3 week intervals until a total time of 2184 hours had elapsed (1458 active "on" time).

As can be seen from the life test data summary in Table II-16, no significant changes in parameter limits were measured, and the variations which occurred are the kind of variations normally associated with these types of measurements.

TABLE II-16. LIFE TEST RBV #S19943 - SUMMARY OF DATA

	2-16-73	10-20-75 Initial	11-14-75	12-24-75	1-21-75	2-13-76	3-9-76
TOTAL HOURS	-	0	302	804	1210	1660	2184
FIL-ON HOURS	-	0	201.9	559.4	803.4	1168	1458.3
Gun Test, Eg_1 (v) for I_K= 2.0 mA	-33.75	-27.43	-31.8	-27.49	-32.47	-33.25	-31.02
I_B (µA), for I_K=2.0 mA	2.6	2.7	2.65	2.65	2.6	2.6	2.65
S/N (db)	31.8	34	34.7	33.7	34.2	34.1	34.3
I_K Leakage (µA)	1.9	3.8	3.0	5.0	5.49	11.0	11.0
SIG OUTPUT - mv	105	170	225	200	215	210	213
MULT, GAIN	135	140	143	167	174	175	178
(CH 2)							
MTF 52 lp/mm	30.4	43	43.4	43.7	43.7	45	46.7
MTF 80.8 "	7.4	13	12.0	11.6	11.4	11	12.8
MTF 90.4 "		6	6.5	5.8	5.7	6	6.4
SHADING H SIG (%)	19	28.7	25	24	20.2	22	18.4
H BLK (%)	37	40.0	57	50	40.0	42	45
V BLK (%)	56	9.5	6.4	10	17.0	14	17.8
V SIG (%)	16	37.5	34.0	42	31.0	28	31

The grid bias to produce 2 mA cathode current in the gun test showed scattered variations within the range of -27 volts to -33 volts which indicates that there was no degradation of the cathode emission during the test. This is verified by the nearly constant beam current, I_b (2.6 to 2.65 μA).

The signal-to-noise variations lie within the range of 33.7 to 34.7 dB, within the range of measurement variations normally experienced. The cathode leakage showed a progressive increase of 3 to 11 μA during the test, a final figure still lower by a factor of 5 to 6 from many other acceptable vidicons.

The signal output varied from 170 to 225 mv, a variation low compared to many vidicon tests. Likewise, the measurement of multiplier gain within the range of 140 to 178 showed no progressive change. The values of MTF between the range of 43 to 46.7 for 52 line pairs showed no significant change. Figures for higher line numbers are similarly consistent, as are the values for shading.

This vidicon has a dimly visible horizontal line which is the result of an incident of faulty operation of the test equipment and has no bearing on the life test.

It was concluded that this RBV has performed under life test in a most acceptable manner and that there is no evidence of deteriorated performance.

7. Basis for Selection

The Return-Beam-Vidicons for Landsat C, as mentioned earlier, were selected from the residual stock of the Landsat 1 and 2 program. A vidicon to be useable should be relatively free from spots and blemishes, should have a shading factor which may be readily compensated for, should resolve detail at 90 line pairs/mm with at least 3% MTF, and should have a Signal-to-Noise ratio of at least 33 db. Since both the shutter time and readouts are staggered, it is required only that the image be stored

without degradation for the duration of the 3.5 second readout interval following exposure. This is a relaxed requirement from that of Landsat 1 and 2. Additional factors considered are concerned with cathode slump between tests and its capability of recovering, and its consistency of performance on successive tests.

8. Available Stock

As indicated previously, there was a residual stock of Landsat 1 and 2 Return Beam Vidicons. Some were immediately rejectable as flight quality vidicons because of observable defects such as spots and blemishes or mottling, or lack of a suitable signal-to-noise performance, or poor resolution.

There were 14 satisfactory vidicons, including S19919 which was previously installed in the camera presently identified as the Design Qualification Model for Landsat-C.

The others are listed below:

P06557
S19917
S19929
S19930
S19931
S19936
S19941
S19944
S19945
S19947
S19948
S19951
S19952

Initial testing of these vidicons found that S19929, -31, -36 and -45 needed to be placed in a cycling operation to reactivate cathodes whose emissions were not adequate. While all the vidicons being considered met the minimum resolution requirement, it

was noted that S19917, -36 and -41 had lower resolution than the others. Also all vidicons met the minimum requirement of 33 db signal-to-noise ratio but S19947 was close to this figure. With regard to noticeable cosmetic defects, vidicons number S19951 and -52 were observed to have spots on the target or mesh.

Initial judgement as a result of the first test sequence indicated the prime candidates to be S19930, -31, -49, -45 and -48, however, subsequent testing showed S19945 to consistently require recycling and it was replaced by S19936. P06557 was also added to the list of prime candidates.

In December 1975 an evaluation of the available data was made by a selection committee. Members of this committee independently selected vidicons for flight 1 and 2, spare camera and spare vidicon. This selection was based upon: data obtained during the December test sequence; data obtained during previous testing which had been conducted routinely every three months; and a set of monitor photographs which had been made as part of the December check. While the monitor resolution was not great enough to evaluate final resolution of the vidicon it did permit the study of shading and possible cosmetic defects.

Based upon this evaluation, the chart on Figure II-17 was made which lists MTF, signal-to-noise and other pertinent factors. From MTF and signal-to-noise data, a factor of merit, agreed upon by a majority of committee members, was listed in column F/M. F/M Rank lists vidicons in the order of these factors of merit. By considering this and cosmetics, shading and past history of performance the committee developed an overall rank column, shown to the left. Four vidicons, S19917, S19930 S19931 and S19947 were selected for flight status, with S19944 as the next backup.

Subsequent testing of the selected vidicons included the taking of monitor pictures and careful studying of them to better evaluate cosmetic features and other variations of

TABLE II-17. RBV VIDICON EVALUATION

OVERALL RANK	SERIAL NO.	MTF CHAN 2 AT 52 lp	S/N (dB)		NEED FOR RECYCL.	# HRS	R-RET MAP Q-QUAL	F/M	F/M RANK
9	P06557	.47	37.1 / 36.4		No	184	R, Q	32.33	2
2	S19930	.446	36.7 / 36		No	604	R	28.5	5
3	S19931	.395	36.8 / 36		No	180		26.1	7
11	S19936	.39	35.7 / 35.2		YNN	92		23.2	10
5	S19944	.39	35.6 / 34.7		No	80		22.3	12
7	S19948	.45	35.6 / 34.5		No	97		25.3	9
1	S19917	.37	38.7 / 37.7		No	222	R	30.1	3
12	S19929	.45	38.2 / 37.5		YYN	331	R, Q	35.1	1
8	S19941	.36	36.4 / 35.3		No	66		22.3	11
13	S19945	.46	36.3 / 35.7		Yes	363.8		29.0	13
4	S19947	.43	36.1 / 35		No	137		25.8	8
10	S19951	.42	37.3 / 36.7		NYN	99		29.7	4
6	S19952	.42	36 / 35.8		No	104		26.2	6

NOTES: Column 4 – S/N in dB – high/low figures for last three tests.

Column 6 – Need for recycling. "No" indicates cathode rejuvenation by cycling was not required on the last three tests. "YNN" means recycling on the first of final three tests but not on second and third etc.

Column 9 – F/M: Figure of merit which is the product of MTF at 52 line pairs per mm and signal-to-noise ratio.

picture quality. The monitor permitted evaluation over the faceplate, rather than the picture center measurements made in the routine exercise-and-test routines. This testing revealed that RBV #S19947 showed a difference of resolution from the top to the bottom of the picture. The point of best focus could be changed in position by varying the focus electrode potentials. This indicated the existence of a tilted or non-flat mesh. As a result S19947 was replaced by S19944 as a selected vidicon.

9. Final Assignments

The final vidicon assignment was: Flight 1 (Serial 102), Vidicon Number S19930; Flight 2 (Serial 103), Vidicon Number S19931; Spare Camera (Serial 101), Vidicon Number S19944; Spare Vidicon, S19917; and Qualification Model, S19919.

10. Vidicons for Possible Future Use

The 8 vidicons remaining which could be considered for future flight use are, in order of acceptability: S19952, S19948, S19941, P06557, S19951, S19936, S19929, S19945. Reviewing the characteristics, there are no major problems which would prevent these from being considered for future flight use. However, it should be noted that S19951 and -52 have noticeable cosmetic blemishes; and S19945 needed to be recycled at each exercise period.

11. Processing Cycle

After selection, the vidicons were subjected to the following processing schedule:

Mechanical
Pre-Vibration check of characteristics
Mount in vibration fixture
Vibrate fixture and vidicons
Post-Vibration check of characteristics
Make pictures from Picture Monitor

Solder leads to base
Apply potting to base and leads
Make x-ray inspection of potted vidicon
Mechanical Inspection
Post-potting test of characteristics
Make pictures from Picture Monitor
Map reticles at USGS, Reston, Va.
Pre-Hi pot check of characteristics
Hi-pot test for arcing and corona
Post hi-pot gun tests
24-hour test
Apply black mask to faceplate
Review all data
Install in camera
Exercise and test at 3-month intervals

Some problems existed during the processing of the vidicons. To check the potting process, an operable but not-flight-quality tube was subjected to the potting schedule to uncover possible problems. The soldering of leads and potting was done at RCA's Lancaster plant. The process was to be a repeat of the processing done on the Landsat 1 and 2 vidicons.

The first problem was the discovery of a slightly bent base pin on S19917. This had caused a very small chip in the glass fillet. Common practice with similar conditions on commercial vidicons is to straighten the pin and use as is.

However, because of the extreme care required for space qualified components it was decided to use S19917 as a vidicon spare for Landsat C.

The second problem was the existence of voids in the x-ray pictures of the potted vidicon. After stripping and repotting a sample with a different material, DC 93-500, and using a modified prepotting cleaning procedure, improved conditions were obtained. There did remain, however, some delaminations at the glass

interface which were subject to question. The vidicons were subsequently tested by applying a 10^{-5} Torr vacuum for 8 hours and applying high voltage. No problems resulted. To provide added assurance of safe operation, a vent hole was drilled in the potting to facilitate the outgassing process, during test and space usage.

12. Exposure Analysis and Recommendations

A vidicon exposure analysis was conducted under a modification to the contract. The purpose of this study (see Ref VII C7: Exposure Analysis and Recommendations for Landsat C/RBV September 1976) was to analyze the pictures from Landsat-2, relate them to conditions of Landsat-C, and compare this data to the theoretical calculations based on the performance of vidicons measured in the laboratory. NASA made available more than 500 Landsat-2 pictures taken from 37 orbits occurring in January, February and July of 1975.

Typical orbits were selected and the results of evaluation of each picture were averaged. This data was then adapted to Landsat-C conditions and parameters. This resulted in a value of Exposure Constant (Exposure, times the sine of sun elevation angle) equal to 1.91×10^{-3}.

Using this value of Exposure Constant (EC) the shutter time may be programmed during any planned orbit by selecting the nearest value of the five available shutter speeds between 2.4 and 12 milliseconds according to the equation:

$$\text{Shutter time} = \frac{1.91 \times 10^{-3}}{\text{sine sun el}}$$

The study verified that the range of available shutter times chosen for Landsat C provided an adequate selection of programmed exposure times within orbits extending from the Tropics to well above the Arctic Circle in both Summer and Winter. The study also showed that it is possible to choose a nominal fixed value of shutter time for any orbit, based on the above formula, which

will permit optimum exposure for the central portion of the North American continent with only some minor under-exposure in the Arctic regions, and some minor over-exposure in the tropical regions. Thus, the proper choice of a single exposure time for a given orbit permits the use of the normal photographic latitude of the RBV photoconductor in a way that will provide reasonable picture quality from the Arctic regions, Northern Canada and Alaska, to the Gulf of Mexico.

The compromise of fixed shutter time per orbit means that the pictures would probably suffer some underexposure in the far North and would show saturation on white clouds and other bright areas in the equatorial zone.

13. Adapting Landsat-2 Data

The adaptation to Landsat-C conditions involves a correction from the Channel 2 (0.58 to 0.68 micrometers) condition of Landsat-2 to the white-light (0.5 to 0.83 micrometers) condition of Landsat-C. There is also a change in lens focal length and f/number from 126 mm, f/2.8 to 236 mm, f/2.9.

The vidicon performance was calculated in two other ways:

1. Using measured RBV sensitivity and assumed spectral radiances of types of earth scene.

2. Use of a formula from CONFIGURATION AND PERFORMANCE STUDY REPORT (July 1973). Camera signal current was developed in terms of spectral band, RBV spectral response, filter factors, anticipated input radiance, slope of the light transfer curves, shutter speed and lens speed.

The three sets of results are summarized in the following table:

EXPOSURE CONSTANT

Calculated from Landsat-2 Pictures	$= 1.91 \times 10^{-3}$
Calculated from Laboratory Curves and Radiance Measurements	$= 1.53 \times 10^{-3}$
Calculated from Assumptions of 1973 Study	$= 1.49 \times 10^{-3}$

The above comparisons indicate that the earlier theoretical considerations were very slightly optimistic, approximately 1/2 gray step.

The very close agreement lends confidence that the figure of EC of 1.9 x 10-3 forms a firm basis for calculating shutter exposures as a function of sun elevation for Landsat-C.

If the assumption is made that the shutter time is programmed during a given orbit, it should be possible to obtain optimum exposure through the orbit, and to a sun-elevation angle of 9^{o}, (maximum setting of 12 ms), equivalent in winter to a latitude of about 60^{o}N. Since the terrain in winter is mainly ice and snow with low contrast, acceptable pictures with a sun elevation angle as low as 2.3^{o} could be obtained. In the equatorial region a sun angle of 90^{o} with a shutter time of 2.4 ms would produce only a very mild overexposure of 1/2 gray step.

In summer, pictures in the Arctic may be properly programmed as far North as is desired, and the 90^{o} sun elevation would again require the minimum 2.4 ms exposure time.

In summary, nearly correct exposure from Tropics to Arctic Circle can be programmed during any orbit, summer or winter, by shifting to any one of the 5 exposure times (2.4, 4.0, 5.6, 8.0 and 12 milliseconds) at appropriate intervals. If programming

C-2

is not convenient a nominal mid-orbit shutter value may be used. For the range of 9° North to the Tropics a 6.3:1 ratio of exposure values will be experienced (5.5 gray steps) which is within the dynamic range of the vidicon. The pictures would suffer some under-exposure in the far North and white saturation on white clouds and other bright areas in the equatorial zone. However, the pictures should still be of reasonable quality, such as comparable to those received from Landsat-2.

SECTION III

TEST AND RECEIVING SITE EQUIPMENT

A. GENERAL

The Ground Equipment consists of the following units, each one having a distinct and separate function:

- Vidicon Imaging Assembly Test Set (VIATS)
- Collimators
- Special Test Equipment (STE)
- Bench Test Equipment (BTE)
- Receiving Site Equipment (RSE)

The modifications required to each unit will be discussed in the following paragraphs. A brief introductory section describing the equipment precedes each description of the modification.

Further details of the ground equipment operation and modification can be found in Section VII of the Critical Design Review submission, dated November 6, 1975 (Ref. VII-C-3).

B. TEST EQUIPMENT

1. VIATS (1 Unit)

The Viats equipment, which is shown in Figure III-1, is used to evaluate and test the integrated imaging assembly, including vidicon, deflection coils, alignment coils, focus coils, erase lamps, shutter, thermoelectric cooler, and lens.

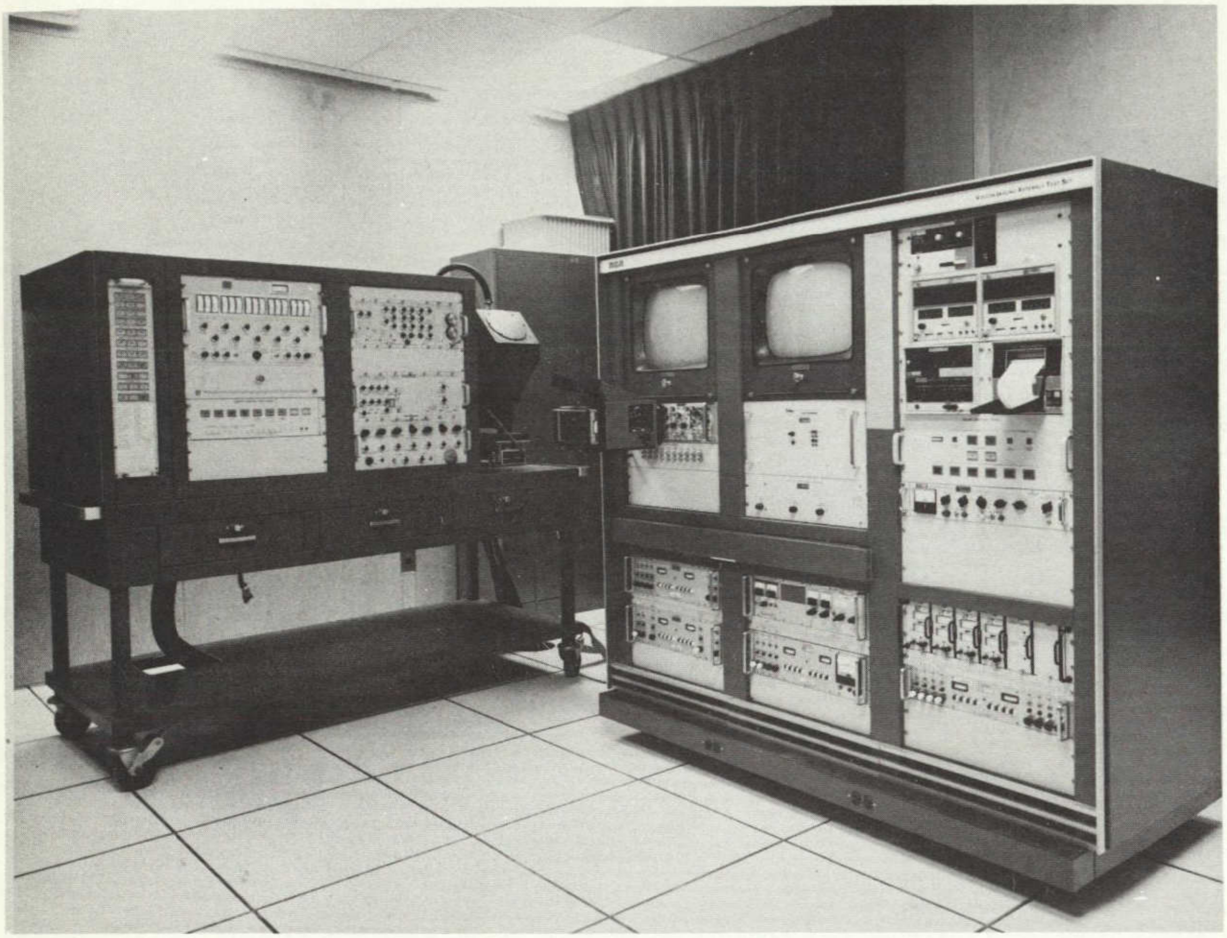

Figure III-1. Vidicon Imaging Assembly Test Set (VIATS)

VIATS provides a means of proving the ability of the integrated imaging assembly to meet the specification requirements and of rapidly determining the operating parameters (vidicon electrode potentials, focus current, etc.) for optimum camera performance. In the general operation of VIATS, the input to the assembly is an imaged test pattern provided by a collimator (generally the collimator which will be used with the camera throughout its test cycle). A video signal is obtained from the vidicon and displayed on a monitor and an oscilloscope. Sensor performance is optimized by adjusting operating potentials, the focus and alignment coil currents, and optical focus.

Performance is evaluated by observing and measuring signal characteristics such as resolution, shading, signal-to-noise ratio, etc. Operating conditions under which optimum performance is obtained are measured and recorded. Thus, VIATS is the vehicle

used to determine that the imaging assembly qualifies for further integration into a camera and to obtain a record of the measured operating conditions under which the performance was obtained (for use during final camera set up).

To provide VIATS compatibility with the Landsat-C/RBV requirements, controller modifications were implemented to change the Erase/Prepare time from 14.5 seconds to 9.0 seconds and the overall cycle time from 25 seconds to 12.5 seconds. In addition, the sensor mounting platform was modified to accomodate the Landsat-C sensor and collimator. No other modifications were required.

2. COLLIMATOR (4 Units)

The collimator focal length, 59.7 centimeters, has been chosen so that the magnification between the target plane in the collimator and the image plane of the lens (when both are in vacuum) is exactly the same as in the Landsat 1 and 2 three-camera RBV system. This permits reuse of the collimator targets from the earlier program, which in turn permits reuse of the software associated with camera testing. It also allowed reuse of the entire rear assemblies, containing lamps, targets, filters and condensing system, from the previously supplied collimators; so the design and manufacturing effort for the collimator procurement was restricted to the collimating lens function of the collimator. Modifications to the rear end assemblies consisted of inclusion of a 1.8 millimeter thick Schott BG34 filter to flatten the spectral output of the collimator, and redesign of the condensing lenses.

The collimating lens design meets the critical requirement for athermal performance in vacuum, and for focusing capability to permit camera testing in air and in vacuum without refocusing of the camera lens. Both these requirements are satisfied by controlled movement of the field flattening lens (the negative lens closest to the target plane). The lens movement required

for athermalization is provided by rods which have a thermal expansion coefficient different from that of the lens barrel, and move the cell containing the lens (with respect to the barrel) as a function of temperature. Superimposed on this motion is a micrometer driven motion which moves the lens within its cell. Hard stops are provided for the two most used focal positions; infinity focus in vacuum and a focal position in air which focuses the collimator target at the vidicon faceplate of a camera in air, with its lens focused for infinity in vacuum. This provides accurate and positive adjustment of the lens for these two positions. The micrometer drive also provides a continuous focusing capability which is useful in checking the accuracy of the hard stop focal positions.

3. STE (2 Units Modified)

The Special Test Equipment STE shown in Figure III-2 is designed for use in testing a single camera of the RBV system. The major components of the STE are:

- Single Camera Console (SCC)
- Single Camera Mobile Mount (Test Cart)
- Quick Look Monitor (QLM)
- Computer System

The STE Single Camera Console is the central unit providing signal inputs, commands, and power to operate and functionally exercise the RBV single camera. It also provides the means of monitoring the video and telemetry outputs of the camera and of making measurements of high accuracy. The QLM incorporates a low resolution display providing rapid access to the displayed video through the use of Polaroid photographs. The Computer enables acquisition and evaluation of video and telemetry data. The Test Cart provides a facility for mounting and positioning the Single Camera and collimator, as well as providing the electrical interface between the SCC and Single Camera. A block diagram of the STE is shown in Figure III-3.

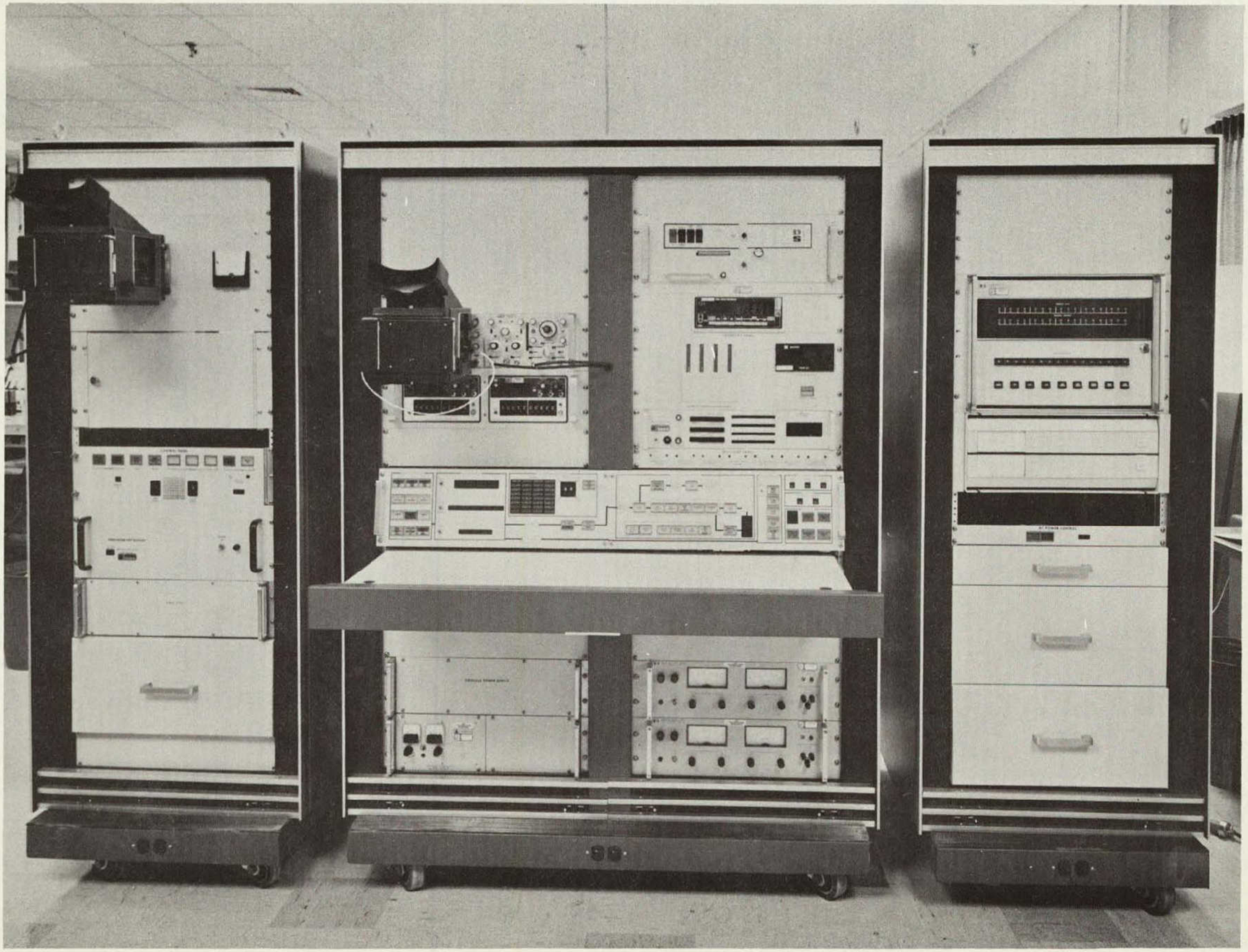

Figure III-2. STE

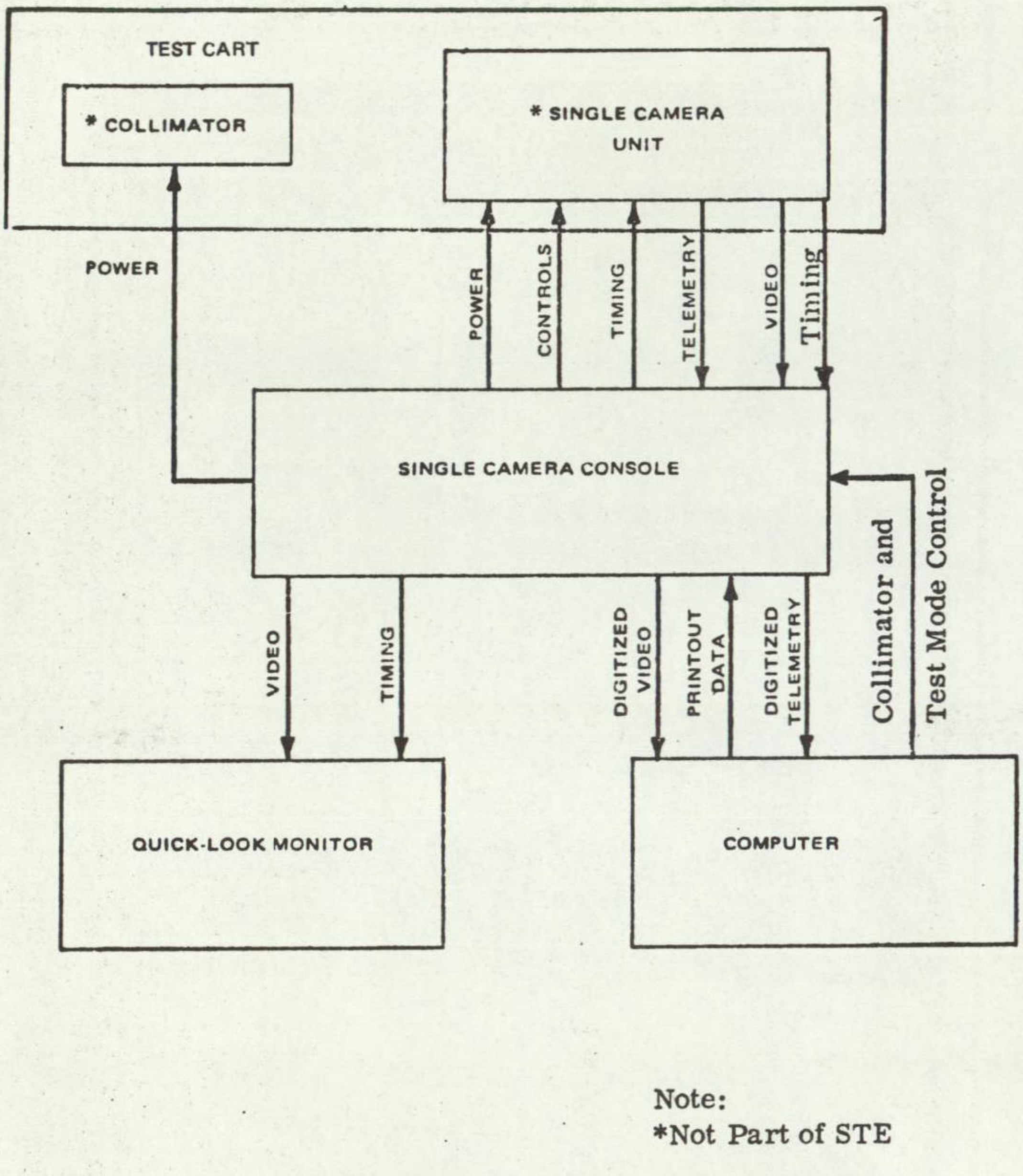

Figure III-3. STE Block Diagram

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Only the Single Camera Console and Test Cart required modifications for use with the two-camera system. Since the requirement for Three-Camera operation no longer exists, the modified STEs are capable of two-camera operation only. A brief description of the operation of the major components in the STE is given in the following paragraphs.

a. Single Camera Console

The Single Camera Console interfaces with the camera under test, distributes data to the Computer, and video to the Quick Look Monitor.

The console provides control signals, timing signals, and power to the camera under test and monitors the telemetry and video output of the camera. The console contains a Test Pattern Generator (TPG), which simulates the camera system outputs allowing test system checkout. The video and telemetry processing circuits, necessary to provide the data in a digital format to the Computer, are contained in the console. The console also provides video and timing signals to the Quick Look Monitor.

b. Camera Controller Simulator (CCS)

The CCS provides the gating logic for the output timing and control signals to the single camera system. In this way it simulates the timing and mode control functions of the Camera Controller and Combiner (CCC). The Single Camera Console control panel provides simulated spacecraft commands to the CCS via the Command Simulator. These commands determine the timing and modes of operation of the CCS. The CCS receives much of the timing and control signals from the simulated Camera Controller and Combiner portion of the TPG. The CCS interfaces with the single camera system via a Buffer Box located on the Test Cart.

The following changes were incorporated into the CCS for two-camera operation:

Cycle Time - Changed from 25 to 12.5 sec

Erase/Prepare Interval	-	Changed from 14.5 sec interval to 9 sec interval
Shutter Speeds	-	Changed from existing times to 12, 8, 6, 4 and 2.5 msec

All changes to the CCC have been reflected in the CCS.

The CCS has been completely redesigned to allow it to conform with the Camera Controller & Combiner on a 1 to 1 basis.

Wherever possible, all of the interfaces with either the TPG or the control and display portions of the STE were made so as not to disturb the 1 to 1 relationship. Exceptions to this are the commands from the STE where switch contacts or TTL logic was used in place of relay contacts, and where signals for test and display purposes in the STE had to be incorporated.

Not included in the CCS are the command relays, telemetry signals, the 1 Hz and Rephase A&B signals from the spacecraft and the +6V filter network.

The CCS/Buffer Box interface exactly simulates the CCC/Camera interface.

c. Test Pattern Generator (TPG)

The Test Pattern Generator in the SCC produces a simulated camera Video Signal. Twenty-nine individual patterns can be provided during any of the read intervals.

In addition to the normal operating modes, the TPG incorporates a Continuous Read mode for special tests. In Continuous Read mode, the TPG repeats the Read 1 interval, providing essentially continuous video. The SCC TPG was not required to retain three-camera-system capabilities. All TPG changes are similar to those in the CCC. Every attempt was made to provide a 1 to 1 correspondence in all changes so that the CCC design was verified as part of the TPG modification. All changes are to the logic nest located on the lower frame behind the control panel.

The pattern generation section of the TPG remains unchanged but the Simulated Camera Controller and Combiner section required extensive modification.

d. Buffer Box

The buffer box located on the Test Cart provides the interface between the Single Camera Console and the single camera system. The output gates have been changed to reflect the new output circuitry incorporated into the CCC. The buffer box uses the same type gates as used in the CCC.

4. BTE (2 Units)

The BTE, shown in Figure III-4 is used to completely test and evaluate the RBV Two-Camera Subsystem. The BTE contains the following six physically and functionally separate units interconnected with power and signal cables as shown in Figure III-5, the BTE Simplified Block Diagram.

- Three (Two) Camera Console (TCC)
- Three (Two) Camera Test Cart (TCTC)
- Quick Look Monitor
- Electron Beam Recorder
- Wide Band Video Tape Recorder
- Computer Cabinet and Teleprinter

The TCC provides two major functions:

- Simulation of spacecraft supplied signals, and
- Evaluation of data obtained from the RBV system under test.

The simulation function consists of supplying power, commands and timing signals, as well as light stimulus to the camera system. The evaluation function consists of converting the video and synchronization signals from the camera system into formats compatible with the display and recording units of the BTE. The TCC has the capability of sampling selected video data and converting the analog sample into a digital format compatible with the Computer System.

Figure III-4. Bench Test Equipment (BTE)

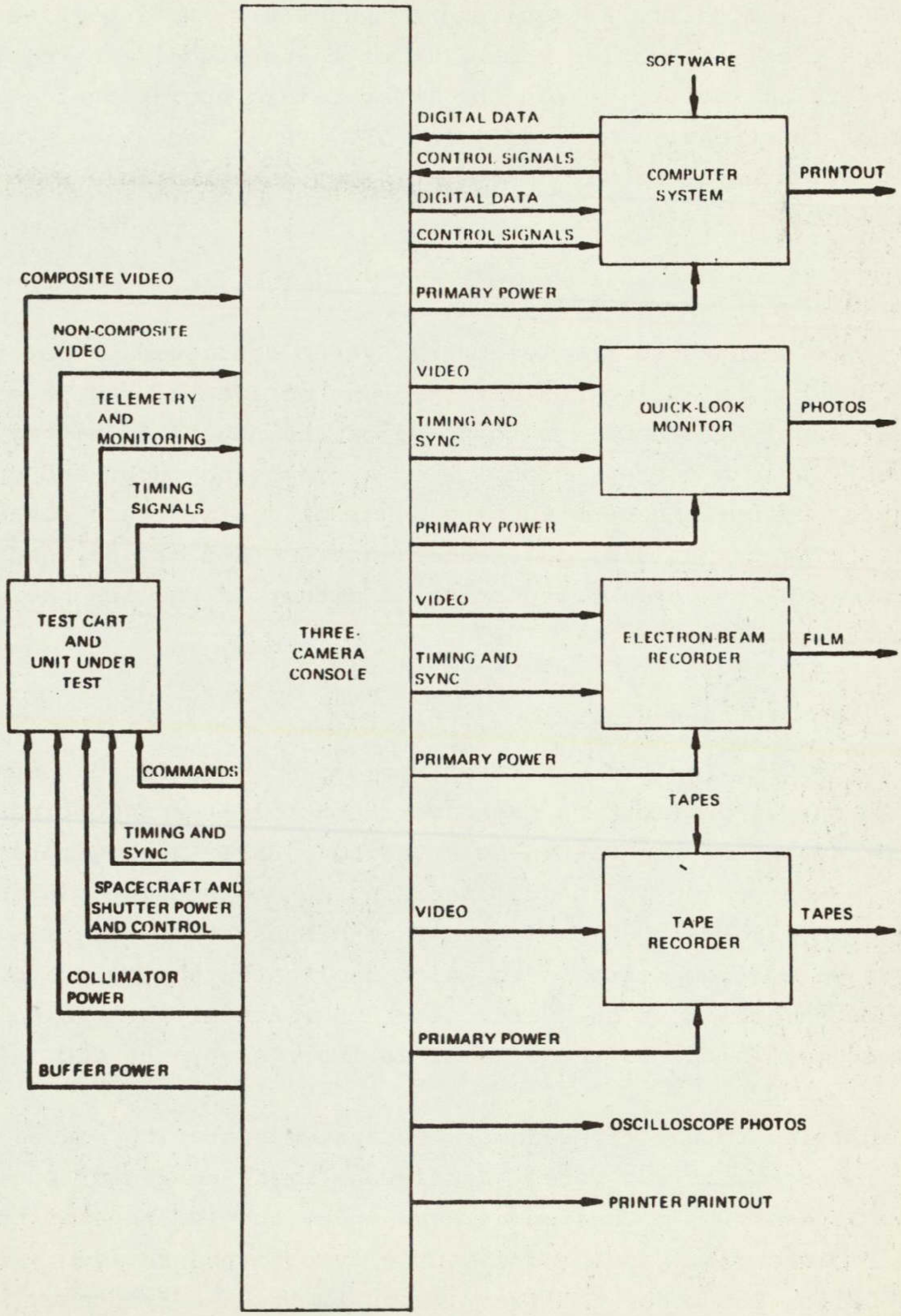

Figure III-5. Block Diagram, Bench Test Equipment (BTE)

Since the TCC may be used to evaluate data obtained via the VPASS, there exists a requirement that the exisiting Three-Camera video evaluation capabilities be retained. There is however, no need to retain the Three-Camera operational (hard wired) functions. Thus, only the TPG, VPASS, and Video Measurements subsystems within the TCC must be compatible with the Three-Camera system.

a. Telemetry Subsystem

The changes to the Telemetry System consisted of deleting the 3rd camera analog board to prevent accidental regulated power supply shutdown due to noise on the unused telemetry lines. This has been accomplished by removing input and output connectors and constructing dummy plugs for these connectors. The camera 3 board remains in place and may be used as a spare in case of a malfunction in either of the two operational boards.

b. Test Pattern Generator (TPG)

The Test Pattern Generator, produces a simulated composite video output duplicating the Camera Controller and Combiner (CCC) output of the Return-Beam Vidicon (RBV) Three-Camera System. Twenty-nine individual patterns can be provided during the read intervals of the Three-Camera Subsystem. The TPG also produces non-composite video which duplicates the output of a single camera minus the vertical and horizontal intervals information, which, in the system, is inserted by the CCC.

In addition to the Three-Camera Subsystem operating modes, the TPG incorporates two modes, Continuous Read and Filter Out, for special tests. In Continuous Read mode, the TPG repeats the Read 1 interval, providing essentially continuous video. In the Filter Out mode, a filter (which limits the frequency response and rise times of the TPG output) is bypassed. A noise shaping network is provided for adding simulated system and link noise to the outputs of the TPG.

c. Video Processor and Sync Separator

The Video Processor and Sync Separator (VPASS), accepts composite video signals from the RBV System via the FM Receiv- ver, a video tape recorder, or video signals from the Test Pattern Generator (TPG). One of the composite video input signals is selected and processed by the VPASS to permit recording, display, or other use of the processed video information. Synchronization and timing signals are extracted from the composite video signal for use by ground support equipment in recording, display, or other utilization of RBV data.

The VPASS consists of a video processor, horizontal sync detector, vertical sync detector, video buffer circuits and logic buffer and line driver circuits. The selected input signal is applied to the video processor, which provides signal buffering, dc level adjustment, amplitude normalization, dc restoration, low-pass filtering, and signal distribution. The normalized video output of the video processor is applied through video buffer circuits to be made available for observation and to the vertical sync detector for sync and timing signal extraction. The dc restored output is applied through the video buffer circuits to the video tape recorder and to the horizontal sync detector for sync signal extraction. The dc restored video signal is also controlled by timing signals from the horizontal sync detector. The filtered video output of the video processor (both filtered and dc restored), is applied to the video buffer circuits, which provide three outputs for display, recording, and spacecraft time decoding.

The horizontal sync detector receives the dc restored and filtered video signal from the video processor and derives information which is utilized to generate output signals at the horizontal sync input rate. Time reference for dc restoration and vertical sync detection are also provided by the horizontal

sync detector. The outputs of the horizontal sync detector are applied through the logic buffer and line driver circuits for use by ground displays and other support equipment.

The vertical sync detector circuit receives the normalized composite video signal from the video processor and detects and verifies the presence of certain frequency, amplitude, and unique sequence elements, which constitute vertical sync. On detection and verification of vertical sync, the vertical sync detector circuits provide control signals to the horizontal sync detector circuits and properly time-referenced outputs through the logic buffer and line driver circuits for control of displays and other support equipment.

The logic buffer and line driver circuits provide isolation and the proper polarity, amplitude, dc level, and source impedance for the succeeding equipment.

The following VPASS modification constraints were followed:

- Operation with both two- and three-camera formats.
- No operator required switchover between formats.
- Minimal VPASS alteration.
- Compatible with existing display and recording devices.

The effect of the two-camera format on VPASS was investigated and it was determined that a third frame (dummy frame) should be added to the format to minimize the changes to VPASS, the Video Measurement Subsystem, and the Computer Software.

These modifications were installed in both BTEs.

d. Three (Two) Camera Test Cart (TCTC)

The TCTC were modified to accept the new collimators. The original collimator mounts were retained since they offer four degrees of freedom, X-Y Translation and angular control in azimuth

and elevation. An adapter plate attaches the collimators to the collimator mounts. The collimator mounts were repositioned on the BTE baseplate to allow for increase camera and collimator length. To accommodate the pitch angle of the two cameras, each collimator was mounted on an adapter plate having a wedge angle of 1.71°, one positive and one negative (total angle between collimators of 1.42°). Roll axis was set by collimator mount location and the adjustment available in the mounts.
The camera baseplate sits on standoffs similar to the previous method.

C. RECEIVING SITE EQUIPMENT (RSE)

The Receiving Site Equipment is part of the ground support equipment for the RBV system. The basic RSE configuration (designated RSE 01) is used at Goddard Space Flight Center, while two similar units (designated RSE 02 and 03) are used at Goldstone, California and Fairbanks, Alaska. The RSE units are shown in Figure III-6 and III-7.

Each of the RSE's are essentially the same, except for the monitor. RSE 01 has a Quick Look Beta Monitor cabinet, while RSE 02 and 03 have built in Conrac displays.

The RSE is designed to accept any one of three composite video inputs: Composite Video A, Composite Video B, or Composite Video C. These signals are normally Test Pattern Generator (TPG) simulated video, tape recorder playback video, and FM received video, respectively.

The RSE provides video, horizontal, and vertical timing signals that are required to process the selected video input. It also contains a Test Pattern Generator (TPG) that is used to test and calibrate the Video Processor and Sync Separator (VPASS) and to simulate noise inputs. An oscilloscope with camera is provided

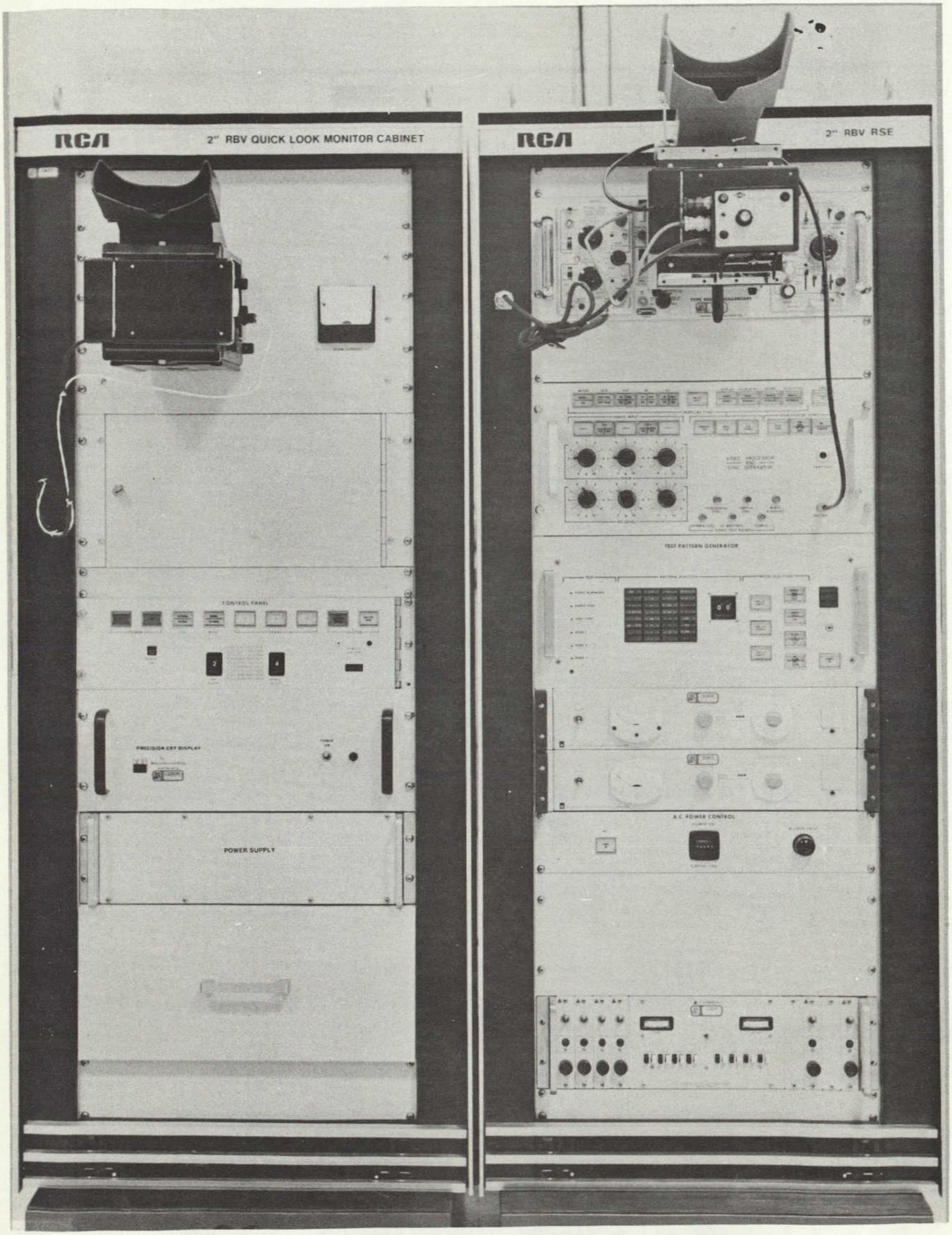

Figure III-6. RSE (01)

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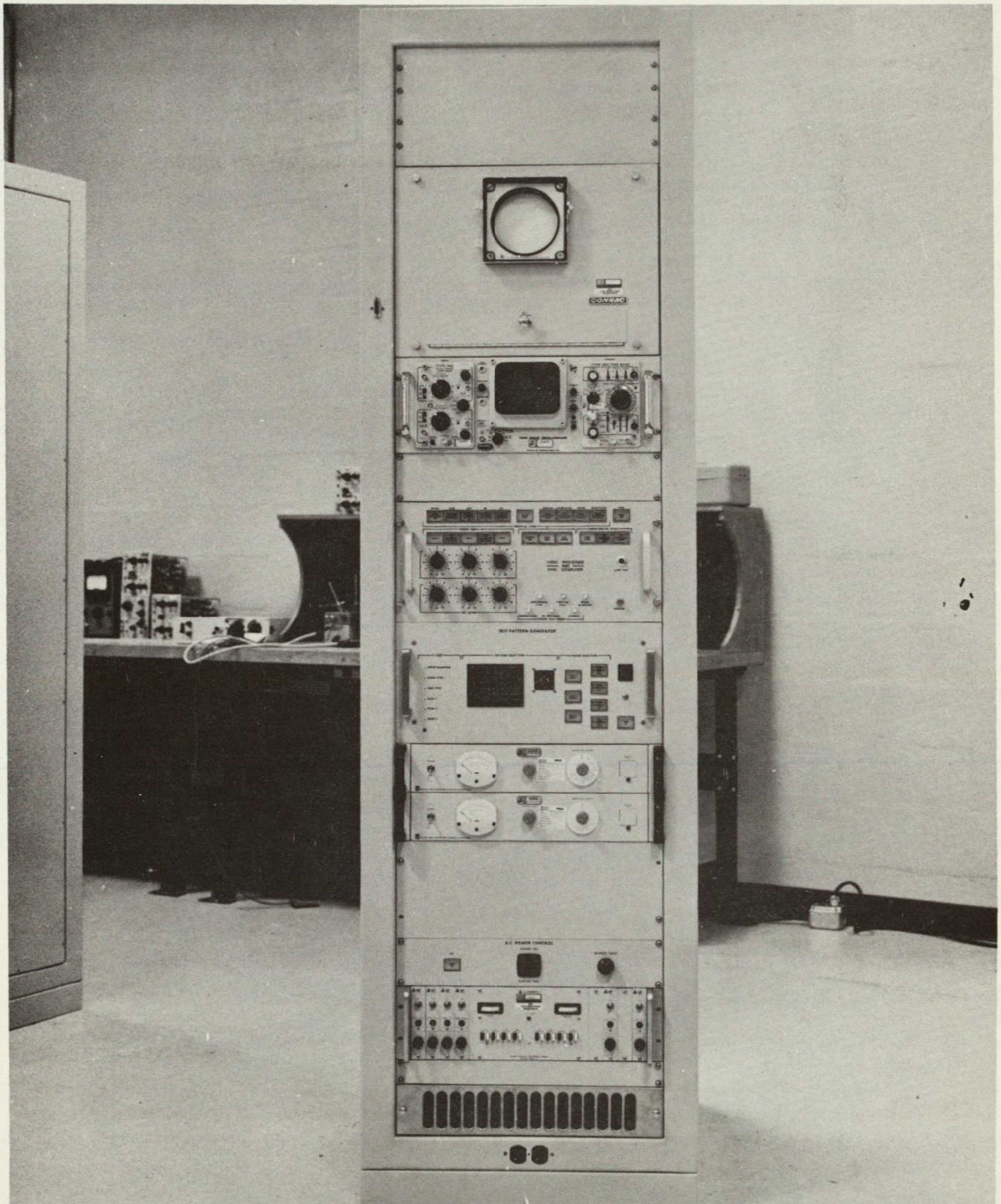

Figure III-7. RSE (02, 03)

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for monitoring and recording video and timing signals from the various test points provided on the VPASS front panel.

The RSE system operates as a self-contained unit requiring no additional ancillary units, other than peripheral receiving and recording equipment, to process video suitable for recording and display.

The VPASS, which is the central processing unit of the RSE, accepts any one of the three possible composite video inputs for processing as determined by the front panel controls and indicators. The VPASS provides horizontal driving signals, vertical driving signals, and video as outputs.

The TPG provides the self-test capability for the RSE. A composite video signal is provided by the TPG as an output to both the VPASS and the loop simulator via the Interface Bulkhead Assembly. The TPG can provide 29 different patterns in the composite video format. These patterns include gray scales, horizontal and vertical bursts, windows, and crosshatches. An additional feature of the TPG is the capability of accepting random noise inputs and shaping them to simulate added noise to the system. For this purpose, two random noise generators are supplied with the Console Assembly.

The Console Assembly also contains an AC Interface Chassis, which distributes power to the rack, and a rack blower. Also included is an AC Control Panel, which controls the main ac power to the rack, an elapsed time indicator, and a blower fault indicator. A Tektronix Model R561B oscilloscope is also provided to monitor and display (in real time) data applied to the VPASS. A Tektronix trace recording camera with electronic shutter is provided to record the data on the waveform display.

In the GSFC configuration (RSE-01), a Quick-Look Monitor Console is used as the on-line display device. This rack includes an AC Interface Chassis, a rack blower, and an AC Control Panel, in addition to the associated display electronics. The monitor is a slow-scan device, which accepts the video input with other timing signals from the RSE Console Assembly and displays the video information on a 3 x 3 inch raster. The Quick Look Monitor also has the added capability of selecting one segment of a 9 x 9 matrix and expanding it to the full 3 x 3 inch display. A Hewlett-Packard trace recording camera is also supplied, to furnish a hard copy of the displayed information.

In the Remote configuration (RSE-02, RSE-03) a Conrac Monitor is furnished in place of the Quick Look Monitor Console. This monitor accepts the video and timing signals directly from the VPASS and displays it on a 3 x 3 inch raster. The oscilloscope camera provided is used to record the displayed information in hard copy.

The two units which must be altered to permit dual 2 and 3 camera capabilities of the RSE are the VPASS and the TPG. The TPG and VPASS changes are the same as those mentioned in section III.4 on the BTE, and discussed in References VII-C-3 and 8.

SECTION IV

PROGRAM TEST CHRONOLOGY

A. GENERAL

The design modifications for the Landsat-C RBV cameras were first incorporated into a Design Qualification Model (DQM). The spare camera (TEM-IR) remaining from the Landsat 1&2 program was modified to meet Landsat-C requirements and became the DQM for the Landsat-C program. A newly designed 236 millimeter, f/2.9 lens was required to provide the increased ground resolution. All DQM testing was completed in August 1976.

The flight camera system completed all testing in January 1977, and was delivered to the spacecraft integration contractor on January 31, 1977, the contractual delivery date. The spare camera completed its testing and was delivered at the end of March 1977.

The test chronology and flow for each test model are discussed in the following paragraphs. Also included is a summary of significant anomalies that occurred during the flight test program.

B. DESIGN QUALIFICATION MODEL

1. General

The Design Qualification Model (DQM) test differs from the

flight cameras in that test temperature excursions were 5°C wider at each extreme and vibration levels were higher. (See Tables II-10 and II-11 for DQM levels). A low level vibration survey was performed on the DQM and data evaluated, prior to proceeding with qualification vibration levels. The lens used on this model was also qualified (early in March 1976) prior to installation in the camera. During vibration of the DQM a dummy camera was mounted on the baseplate in the second camera position to provide the same weight and center of gravity to the baseplate as a flight camera.

The performance of the DQM (summarized in the following paragraphs) demonstrated that the design meets the requirements for the Landsat-C mission.

2. Test Flow and Results

a. The DQM camera test flow is shown in Figure IV-1. A summary of significant test completion dates is given below.

- Temperature Testing - Early June 1976
- System Integration and EMI - Mid July 1976
- Qualification Vibration - End of July 1976
- Thermal Vacuum - Early August 1976
- Complete Testing - Mid August 1976

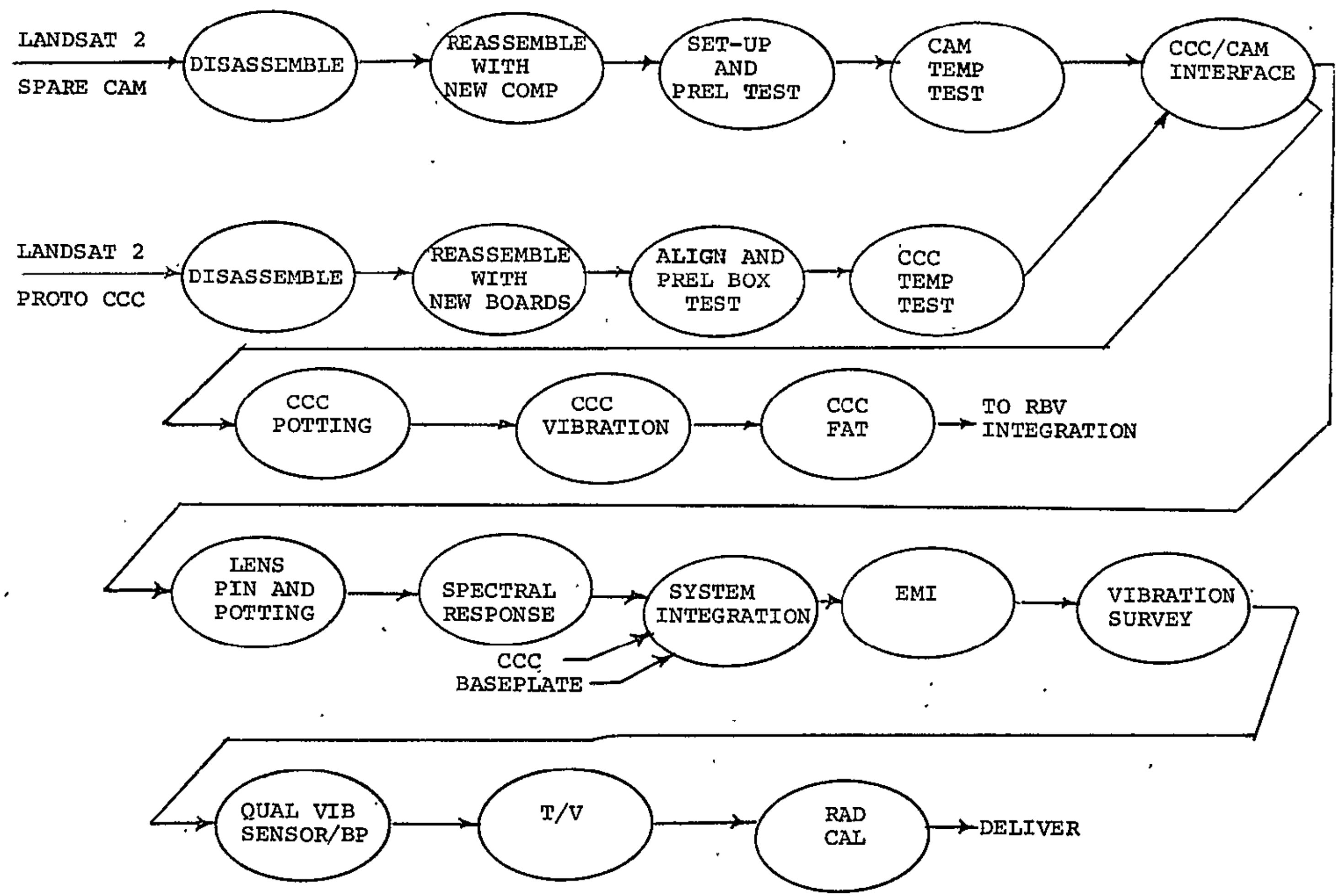

Figure IV-1. DQM Camera Test Flow

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Performance of the DQM is summarized in Table IV-1. All performance requirements were met except for shading and EMI. However, due to redesigned circuitry, shading performance was considerably improved from that of the TEM-IR Camera (as shown in Table IV-2) and EMI performance is unchanged from the TEM-IR, as anticipated, since no modifications were planned in the EMI area.

A comparison of horizontal center resolution for the DQM and the TEM-IR is shown in Table IV-3. The TEM-IR was designed to operate in a narrow spectral band (Channel 2 - 580 to 680 nanometers) while the DQM covers the spectral band from 505 to 750 nanometers. The wider the spectral band, the greater the difficulty in lens design and manufacture, and therefore in achieving specified resolution. The data in Figure IV-3 shows that the resolution of the DQM is comparable to that of the TEM-IR and thus attests to the high quality of the Landsat-C lens. Vertical resolution is given in Table IV-4 and is well within specification.

The shading performance is summarized in Table IV-2 and is compared to the original TEM-IR camera. The significant improvement in DQM overall maximum shading performance is a result of the DQM shading correction circuit modifications discussed earlier.

TABLE IV-1. PERFORMANCE SUMMARY - DESIGN QUALIFICATION RBV CAMERA SYSTEM FOR LANDSAT-C

Description	Spec Value	Actual Value
Highlight Irradiance	(505-750 nm) 2.013 mW/cm^2 - sr	Compliance
Camera Exposures	2.4; 4; 5.6; 8; 12 ms	Compliance
Resolution - Center, Horizontal	4500 TVL	4521*
Resolution - Center, Vertical	3500 TVL	>3403*
Resolution - Edge, Horizontal	3600 TVL	3606
Resolution - Edge, Vertical	2800 TVL	>3403*
S/N (Peak Signal to RMS Noise)	33 dB Min	33.6*
Shading (Within 1" Circle)	15%	19.5%*
Shading (Overall)	25%	37.7%***
Image Distortion	<1%	<1%
Aspect Ratio	1:1 Initially	1.003:1*
Size and Centering	< ±2%	<1%
Residual Image	<3%	<1.59%
Reticle Geometry	9 x 9 Array Sharply Defined	Compliance
Noise Susceptibility	See EMI Table	See EMI Sec.
Electromagnetic Susceptibility	See EMI Table	See EMI Sec.
Power Consumption	142 Watts Avg.	136 Watts Avg.
Weight	170 Pounds	163.6 Pounds

* Taken from 20°C TV data (August 9, 1976).

** One point only; all other edge shading points within 25% spec.

TABLE IV-2. DQM CAMERA SHADING (COMPARE WITH LANDSAT 1 AND 2 SPARE)

SHADING - SPEC: 15% MAX WITHIN QUAL CIRCLE (CENTRAL)
25% MAX OVERALL (EDGE)

	DATA FROM QUALITY CIRCLE AREA			"EDGE" DATA		
	QUAL CAM[1]	TEM 1R[1]	QUAL CAM[2]	QUAL CAM[1]	TEM 1R[1]	QUAL CAM[2]
BLACK TOP (680)	16.6%	10.8	14.2	16.6	25.0	14.3
BLACK CENTER (2065)	13.0%	9.3	12.5	13.0	9.3	12.5
BLACK BOTTOM (3410)	14.7%	24.0	13.0	14.7	40.5	13.0
BLACK VERTICAL	8.3%	11.7	8.8	8.3	11.7	8.8
BLACK QUAL CIRCLE MAX	19.1%	24.0	17.8	--	--	--
BLACK OVERALL MAX	--	--	--	26.8	70.1	23.0
WHITE TOP (680)	11.6%	6.3	11.8	21.9	17.0	22.0
WHITE CENTER (2065)	17.4%	15.0	17.2	17.4	15.0	17.2
WHITE BOTTOM (3410)	6.0%	20.7	6.1	20.8	42.0	21.3
WHITE VERTICAL	16.4%	28.5%	16.2	16.4	28.5	16.2
WHITE QUAL CIRCLE MAX	20.0	28.5	20.2	--	--	--
WHITE OVERALL MAX	--	--	--	34.6	65.5	34.7

NOTE: 1. DATA TAKEN AT 20°C T/V FROM CAMERA AUX. OUTPUT.
2. DATA TAKEN AT 20°C T/V FROM CCC OUTPUT.

TABLE IV-3. HORIZONTAL MTF (CENTER RESOLUTION) - SPEC: 4500 TV LINES A COMPARISON OF QUAL CONFIGURATION AND LANDSAT-2 SPARE CONFIGURATION

		QUAL: 8/76		TEM 1R	
TVL	LP/MM	20^{0} T/V	FINAL	12/72	3/76
2286	45	41.3	43.0	42.3	40.7
2794	55	26.2	28.8	29.0	29.3
2845	59	19.0	23.5	26.9	25.9
3403	67	11.9	15.2	15.0	17.2
4216	83	3.0	6.5	5.8	3.7
4521	89	2.4	4.0	4.5	3.4

TABLE IV-4. DQM CAMERA VERTICAL MTF
(CENTER SPEC: 3500 TVL - 20° T/V

TVL	LP/MM	RESPONSE
1778	35	86.7
2286	45	63.0
2743	54	41.0
2997	59	38.3
3403	67	22.0

Signal-to-noise ratio is shown in Table IV-5. This data is comparable to the original TEM-IR. Size, centering and linearity data is given in Table IV-6.

TABLE IV-5. DQM CAMERA SIGNAL-TO-NOISE RATIO
SPEC: 33 DB MIN

	THERMAL VACUUM				AMBIENT
	35°C	30°C	20°C	5°C	FINAL
S/N (DB)	32.2	32.6	33.2	33.2	33.6

TABLE IV-6. DQM CAMERA SIZE AND CENTERING CHANGES

	PRE T/V 25°C	T/V 35°C	T/V 5°C	T/V 20°C	AMBIENT FINAL	SPEC
VERT SIZE	100.34	100.12	100.36	100.26	100.24	± 2%
VERT CENTERING	.16	.14	.12	.11	.12	± 2%
VERT LINEARITY	<1%	<1%	<1%	<1%	<1%	± 1%
ASPECT RATIO	100.48	99.86	100.34	100.26	100.28	1:1 INIT.
HORIZ SIZE	100.82	100.08	100.71	100.51	100.52	± 2%
HORIZ CENTERING	.44	.14	.53	.26	.29	± 2%
HORIZ LINEARITY	<1%	<1%	<1%	<1%	<1%	± 1%
SKEW						1% MAX

NOTE: IN T/V, THE TEST CHART COULD NOT BE REMOVED CAUSING SEVERAL RETICLES TO BE UNDETECTED; THIS CHANGED RESULTS SOMEWHAT, PARTICULARLY AT 20° (CENTER HORIZONTAL ROW OF RETICLES MISSING).

C. FLIGHT MODEL CAMERA SYSTEM

1. General

The flight model camera system is composed of two cameras mounted on a baseplate plus two camera electronic units and a camera combiner controller (CCC) unit.

The first camera to be built (S/N-101), required additional activation of its vidicon cathode. Because of schedule constraints, it was decided to designate S/N-101 as the spare camera and S/N's-102 and -103 as the flight cameras. The performance of each of the flight cameras was similar to that of the DQM and is summarized in the following paragraphs.

2. Test Flow and Results

The flight camera test flow is shown in Figure IV-2. A summary of significant test completion dates is shown below. (Temperature testing was performed on an individual camera basis.)

- Temperature Testing - Mid November 1976
- Integration of Cameras on Baseplate - Mid December 1976
- Vibration - Late December 1976
- Thermal Vacuum - Mid January 1977
- Complete Testing - Late January 1977
- Deliver to Integration Contractor - January 31, 1977

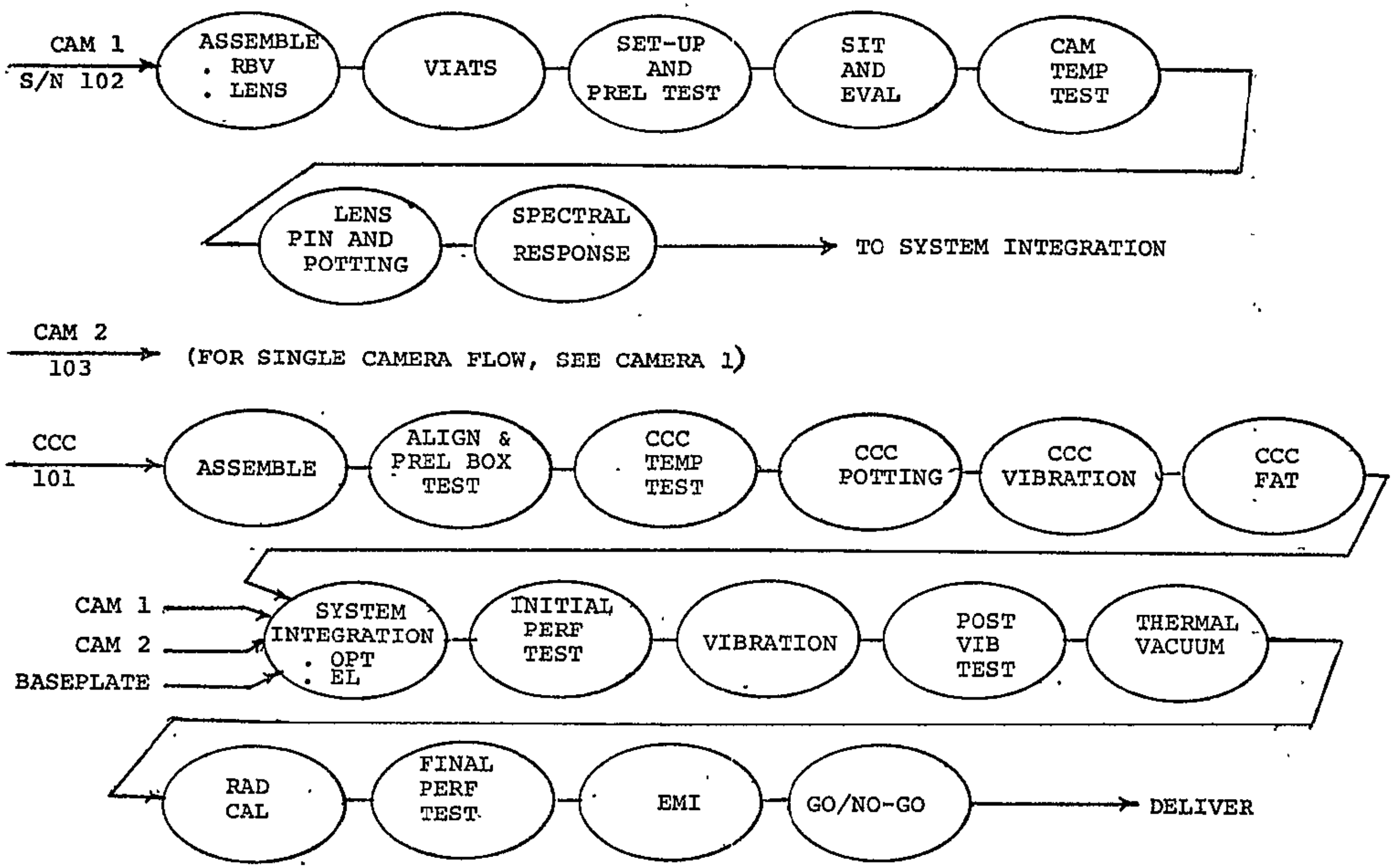


Figure IV-2. Landsat-C/RBV FLT Camera Test Flow

After integration of the flight cameras on the baseplate (including camera alignment), the flight system was subjected to the vibration levels of Tables IV-7 to IV-10. Vibration of the camera electronics and CCC was done separately. After vibration and alignment check, the camera system was subjected to a performance test and a radiance calibration test to verify final camera gain settings, using a calibrated light source.

The camera system was then installed in a thermal-vacuum chamber and subjected to the time-temperature profile of Figure IV-3. Total duration of vacuum testing is approximately 8 days. After thermal vacuum testing the system was subjected to a final performance test.

A summary of flight system performance is given in Table IV-11. Table IV-12 through Table IV-16 provide further detailed performance data for horizontal and vertical resolution, size and centering, shading and signal-to-noise ratio.

3. Summary of Anomalies

A summary of significant anomalies which occurred during the flight system test program is given in the following paragraphs:

a. Vidicon Voltage Variation

During single camera evaluation, a 36 volt variation

TABLE IV-7. SINUSOIDAL VIBRATION LEVELS (CAMERA SYSTEM)

AXIS	FREQUENCY HZ	"G" ZERO TO PEAK
Thrust (Z-axis)	5-50	4.0*
	50-90	7.3
	90-100	3.3
	100-160	2.5 (notch)
	160-320	3.0 (notch)
	320-2000	3.3
Lateral (Y-axis)	5-30	2.5*
	30-50	5.0
	50-270	3.3
	270-370	1.8 (notch)
	370-1600	3.3
	1600-2000	2.0 (notch)
Lateral (X-axis)	5-30	2.5*
	30-50	5.0
	50-175	3.3
	175-250	1.8 (notch)
	250-1400	3.3
	1400-1800	3.0 (notch)
	1800-2000	3.3

* - Exposure limited to 0.50 inch double amplitude.

Sweep Rate: Four (4) octaves per minute.

TABLE IV-8. RANDOM VIBRATION LEVELS (CAMERA SYSTEM)

Frequency (Hz)	PSD Level (g^2/Hz)	Acceleration (g-RMS)	Duration
20	.001		
20-300	Increasing from 20 Hz at a rate of 4 dB/Oct to .04 g^2/Hz at 300 Hz	8.5	1 min per axis
300-2000	0.04		

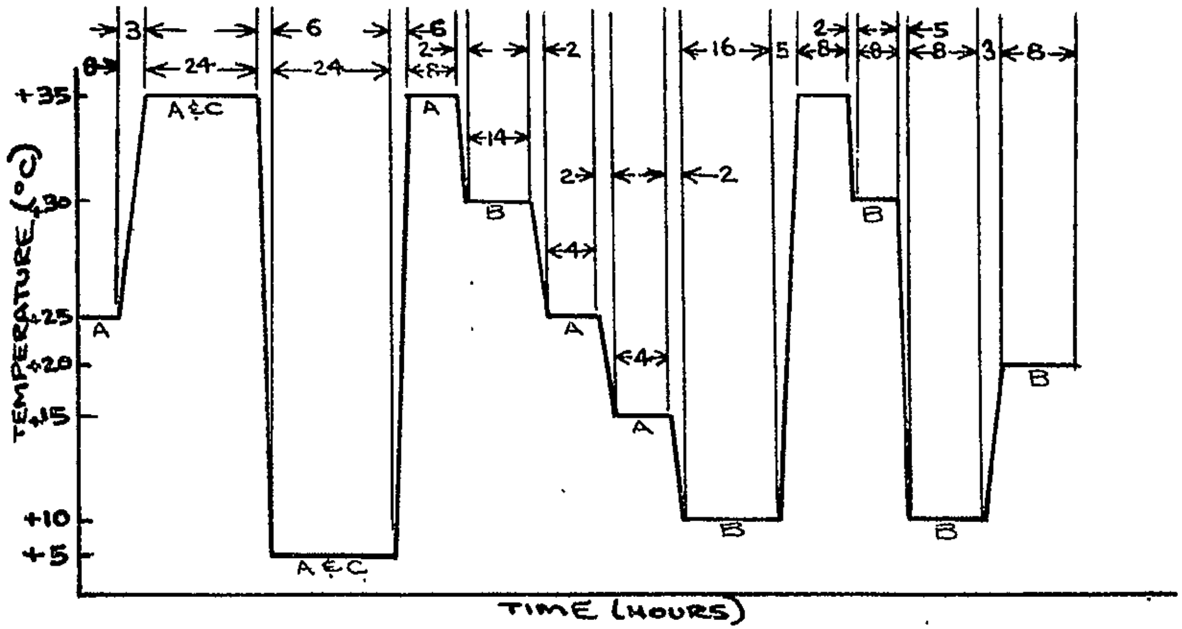
TABLE IV-9. SINUSOIDAL VIBRATION LEVELS (ELECTRONICS)

Axis	Frequency (Hz)	Acceleration (g-Peak) (Acceptance)
Thrust & Lateral	5 - 200	5*
	200 - 2000	3.3
Sweep Rate		4 Oct/Min

*Amplitude limited to 0.5 inch double amplitude (D.A.)

TABLE IV-10. RANDOM VIBRATION LEVELS (ELECTRONICS)

Frequency (Hz)	PSD Level (g^2/Hz)	Acceleration (g-RMS)	Duration
20	0.001		
20-300	Increasing from 20 Hz at a rate of 4 dB/Oct to .04 g^2/Hz at 300 Hz	8.5	1 minute each axis
300-2000	0.04		



TESTING PERFORMED AS FOLLOWS:

A - GO/NO-GO TEST

B - FULL PERFORMANCE TEST

C - 20 MIN ON/80 MIN OFF (QLM PIX)

Figure IV-3. Landsat-C/RBV - Flight Thermal Vacuum Profile, Two-Inch RBV

TABLE IV-11. FLIGHT CAMERA PERFORMANCE SUMMARY

CONTRACT PARAGRAPH	DESCRIPTION	SPEC VALUE	ACTUAL VALUE CAM 1 (102	CAM 2 (103)
3.3.1	Highlight Irradiance	2.013 MW/CM^2 - SR (505-750 nm)	Compliance	
3.3.2	Camera Exposures	2.4; 4; 5.6; 8; 12 ms	Compliance	
3.3.3(a)	Resolution - Center, Horiz.	4500 TVL	4521[1]	4521[1]
3.3.3(a)	Resolution - Center, Vert.	3500 TVL	>3403[1]	>3403[1]
3.3.3(b)	Resolution - Edge, Horiz.	3600 TVL	3606[1]	3606[1]
3.3.3(b)	Resolution - Edge, Vert.	2800 TVL	>3403[1]	>3403[1]
3.3.4	Signal-to-Noise Ratio	33 dB Min	32.6 dB[1,3]	35.5 dB[1]
3.3.5	Shading (Within 1" Circle)	15%	18.7% Max[1]	15.9% Max[1]
3.3.5	Shading (Overall)	25%	29.2% Max[1]	43.5% Max[1,2]
3.3.6	Image Distortion	<1%	1.3%[1,2]	<1%
3.3.7	Aspect Ratio	1.1 Intially	1.004:1[1]	1.0004:1[1]
3.3.8	Size and Centering	< ±2%	<1%	<1%
3.3.9	Residual Image	<3%	<1.5%	<1.63%
3.4.4	Reticle Geometry	9 x 9 Array Sharply Defined	Compliance	
3.4.9	Noise Susceptibility	See EMI Table	See EMI Section	
3.4.10	Electromagnetic Suscept.	See EMI Table	See EMI Section	
3.4.13	Power Consumption	142 Watts Avg.	System Total is 136 Watts Avg.	
3.6.1	Weight	170 Pounds	System Total is 162.34 Lbs.	

Notes: 1. Taken from 20°C T/V data (January 19, 1977).
2. One point only; remainder of field within specification; waiver requested.
3. Waiver requested.

TABLE IV-12. LANDSAT-C/RBV FLIGHT HORIZONTAL MTF
(CENTER RESOLUTION) SPEC: 4500 TV LINES

A COMPARISON OF QUAL CONFIGURATION AND LANDSAT-2 FLT CONFIGURATION

TVL	LP/MM	QUAL: 8/76		CAM 1 (102) 1/77		CAM 2 (103) 1/77	
		20° T/V	FINAL	20° T/V	FINAL	20°C	3/76
2286	45	41.3	43.0	48.5%	47.1%	44.1%	46.4%
2794	55	26.2	28.8	34.1%	35.1%	34.7%	36.8%
2845	59	19.0	23.5	30.8%	30.8%	25.0%	26.7%
3403	67	11.9	15.2	18.6%	19.5%	16.6%	19.1%
4216	83	3.0	6.5	7.3%	7.3%	6.6%	7.0%
4521	89	2.4	4.0	4.6%	5.4%	3.6%	4.9%

TABLE IV-13. LANDSAT-C/RBV FLIGHT
VERTICAL MTF (CENTER)

SPEC: 3500 TVL - 20° T/V

TVL	LP/MM	CAMERA 1 RESPONSE	CAMERA 2 RESPONSE
1778	35	80.07%	80.8%
2286	45	61.22%	57.87%
2743	54	39.56%	37.44%
2997	59	31.26%	30.32%
3403	67	21.37%	20.14%

TABLE IV-14. LANDSAT-C/RBV FLIGHT SIZE AND CENTERING CHANGES

	CAMERA 1 (S/N 102)			CAMERA 2 (S/N 103)			SPEC
	30°C	20°C	10°C	30°C	20°C	10°C	
VERT SIZE	100.36	100.36	100.49	100.23	100.36	100.45	± 2%
VERT CENTERING	+.17	+.20	+.23	.30	.34	.41	± 2%
VERT LINEARITY	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	± 1%
ASPECT RATIO	1:1.007	1:1.004	1:1.004	1:0.999	1:0.999	1:1.001	1:1 INIT.
HORIZ SIZE	99.65	99.95	100.10	100.29	100.39	100.29	± 2%
HORIZ CENTERING	-0.03	0.18	0.38	.16	.22	.38	± 2%
HORIZ LINEARITY	1.3 [3]	1.3 [3]	1.3 [3]	<1.0	<1.0	<1.0	± 1%
SKEW	+.011	+.011	+.08	-.189	-.155	-.211	1% MAX

NOTES:
1. IN T/V, THE TEST CHART COULD NOT BE REMOVED CAUSING SEVERAL RETICLES TO BE UNDETECTED.
2. ALL DATA OBTAINED DURING T/V TEST.
3. ONE POINT ONLY; REMAINDER < 1%
4. ALL NUMBERS IN %.

TABLE IV-15. SHADING - LANDSAT-C/RBV FLIGHT
SPEC: 15% MAX WITHIN QUAL CIRCLE (CENTRAL)
25% MAX OVERALL (EDGE)

	DATA FROM QUALITY CIRCLE AREA			"EDGE" DATA		
	CAMERA 1 (S/N 102)	CAMERA 2 (S/N 103)	QUAL CAM	CAMERA 1 (S/N 102)	CAMERA 2 (S/N 103)	QUAL CAM
BLACK TOP (680)	8.6%	5.7%	14.2	9.3%	11.1	14.3
BLACK CENTER (2065)	6.8%	13.0%	12.5	6.8%	13.0	12.5
BLACK BOTTOM (3410)	7.5%	9.3%	13.0	16.5%	23.9	13.0
BLACK VERTICAL	3.1%	4.9%	8.8	3.1%	4.9	8.8
BLACK QUAL CIRCLE MAX	11.3%	13.9%	17.8	--	--	--
BLACK OVERALL MAX	--	--	--	29.2%	43.5%	23.0
WHITE TOP (680)	17.1%	12.2%	11.8	17.1%	12.2	22.0
WHITE CENTER (2065)	16.4%	6.6%	17.2	16.4%	6.6	17.2
WHITE BOTTOM (3410)	7.6%	5.0%	6.1	14.9	9.4	21.3
WHITE VERTICAL	11.2%	15.1%	16.2	11.2%	15.1	16.2
WHITE QUAL CIRCLE MAX	18.7	15.9%	20.2	--	--	--
WHITE OVERALL MAX	--	--	--	29.0%	25.3	34.7

NOTE: DATA TAKEN AT 20°C T/V FROM CCC OUTPUT.

TABLE IV-16. LANDSAT-C/RBV FLIGHT SIGNAL-TO-NOISE RATIO

SPEC: 33 DB MINIMUM

		THERMAL VACUUM			AMBIENT
		30°C	20°C	10°C	FINAL
CAMERA 1	S/N (DB)	33.2	32.6	32.2	34.2
(S/N 102)	S/N (DB) (WITH A/C)	28.6	29.5	27.9	30.8
CAMERA 2	S/N (DB)	35.0	35.5	34.9	36.2
(S/N 103)	S/N (DB) (WITH A/C)	31.1	31.1	32.0	33.2

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in vidicon G2 voltage was noted on camera S/N-102 between prepare and read modes. Investigation showed the voltage variation was due to the high voltage supply going into current limiting. Substitution of another high voltage transformer provided normal operation. The parameters of the original transformer were measured and a high interwinding capacity was found. The large interwinding capacity caused excessive current to be drawn and resulted in the current limiting operation. Vendor examination of the transformer showed the gap between the ends of the two high voltage windings were too close and not within specification. Additional inspection points were added to the vendor flow to insure future compliance.

b. Incorrect Feed Through Filters

Prior to start of temperature test of the S/N-102 camera, an oscillation was observed in the erase lamp control circuit at turn-on. During trouble shooting, it was noted that the L-C feed-through filters were marked with arrows pointing away from the threaded (ground) end. The arrow indicates at which end of the filter the capacitor is located. The specification requires the capacitor to be at the threaded end. Electrical testing confirmed that the capacitor was incorrectly located at the non-threaded end.

Investigation revealed that a lot of 51 filters were received with incorrect capacitor designation. All filters on boards were then inspected and those with the incorrect configuration

removed and replaced with correct units. No oscillations were observed after installation of properly constructed filters.

c. Focus Current Regulator Interference in Video

During the 5°C temperature test, interference from the focus current regulator (FCR) was noted in the video. Camera S/N 103 exhibited the greater interference, about 5% of the video. As a result of the investigation to reduce this interference, wiring changes were made which reduced the interference by 50%, so that it did not exceed the peak-to-peak random noise amplitude. A review of electron beam recorder (EBR) pictures taken after the wiring modifications were implemented showed no evidence of FCR interference.

d. Lack of +10 Volt (Low Power) Regulator Output - Camera S/N 103

After initial turn on of S/N-103 camera at +5°C, the video level observed at the STE went to +1.6 volts. Normal reading is +1.0 volts. Testing revealed an open base to emitter junction in the +10 volt (video) supply. The harness associated with this supply was carefully examined and the feed through filter was removed and x-rayed. One of the wires associated with the +10 volt line was found to be nicked and two loose solder globules were found in the filter. It could not be absolutely proven whether the cause of the short on the +10 volt line was the nicked wire, or the loose solder in the filter. Note: It was subsequently discovered that this problem may have been caused by excessive turn-on current in the

+10 volt regulator pass transistor as described in paragraph IV-C-3 (e), below. However, repair of the nicked wire and replacement of the filter provided normal operation. As a result of the loose solder in the filter, all filters in stock were x-rayed. Approximately 15% of the parts were found to have internal solder flow. At this point, all filters (of the type in question) were removed from flight hardware, x-rayed and electrically checked. Acceptable units were reinstalled in the hardware. The specification for this filter was changed, so that x-ray examination of all parts is required.

e. Lack of +10 Volt (low power) Regulator Output - Camera S/N-102; (due to excessive Turn On Current in Regulator Pass Transistor)

During testing of S/N 102, an STE panel light indicated abnormal cathode current. In addition, observation of the video showed excessive levels. Subsequent investigation revealed that the +10 volt (video) power line was reading -1.3 volts, and the regulator series-pass transistor showed the emitter lead was fused open indicating a high current stress. Further checks of the circuit board failed to produce a specific cause for the transistor failure. After replacement of the series-pass transistor, the turn on transient through the transistor was measured, and found to exceed the maximum transistor rating. A design change was then incorporated, changing the series-pass transistor from a type 2N1613 to a 2N5154. The latter device is also used in the horizontal deflection circuitry and can safely handle the measured turn on

transient. This design change was incorporated into all cameras (see paragraph IV-C-3(d), above, for description of a similar problem in Camera S/N 103, which was probably a related problem.

In addition, all wet slug electrolytic capacitors on the +10 volt line were replaced because of possible reverse voltage exposure due to the series-pass transistor failure.

f. Black Level Shift

During thermal vacuum testing of the flight system at the +35°C plateau the black level of camera S/N 103 abruptly shifted from 300 mv to 225 mv. This shift was present for two 20 minute periods. Subsequent operation was normal but the anomally reappeared one more time. At the conclusion of the thermal vacuum testing the system was set up in a Tenney chamber where the shift was again observed. The problem was isolated to the high voltage supply. The cause was found to be a cracked zener diode in the high voltage preregulator. The zener diode was replaced and the camera subjected to a six hour test at +35°C. Operation during this test was normal.

D. SPARE COMPONENTS

1. General

The spare components consist of a Camera Sensor, a Camera Electronics unit, and a CCC unit. The tests for these

components followed a flow similar to that of the flight system, except that spectral response and EMI tests were deleted for the spare camera. The spare camera flow is shown in Figure IV-6. Vibration and thermal-vacuum test exposures were identical to the flight system.

The performance for the spare camera is summarized in Table V-17. Horizontal and vertical resolution as measured in the final performance test is shown in Tables IV-18 and IV-19. Shading performance is summarized in Table IV-20 and size and centering in Table IV-21.

The signal-to-noise ratio as measured by computer during the final performance test is shown in Table IV-22. Evaluation of "A scope" pictures showed the actual SNR to be about 33 dB. A check of the bench test equipment (BTE) showed that the noise-measurement circuitry had drifted out of calibration. After this circuitry was properly calibrated the SNR read 33.1 dB, which meets the 33 dB minimum requirement.

2. Test Anomalies

A summary of significant test anomalies occuring during spare camera testing is given below.

a. Video Level Warmup Drift

During evaluation of the spare camera, S/N-101, a video level drift of approximately 150 mv was noted during the first few minutes of warmup. Extensive testing showed the cause

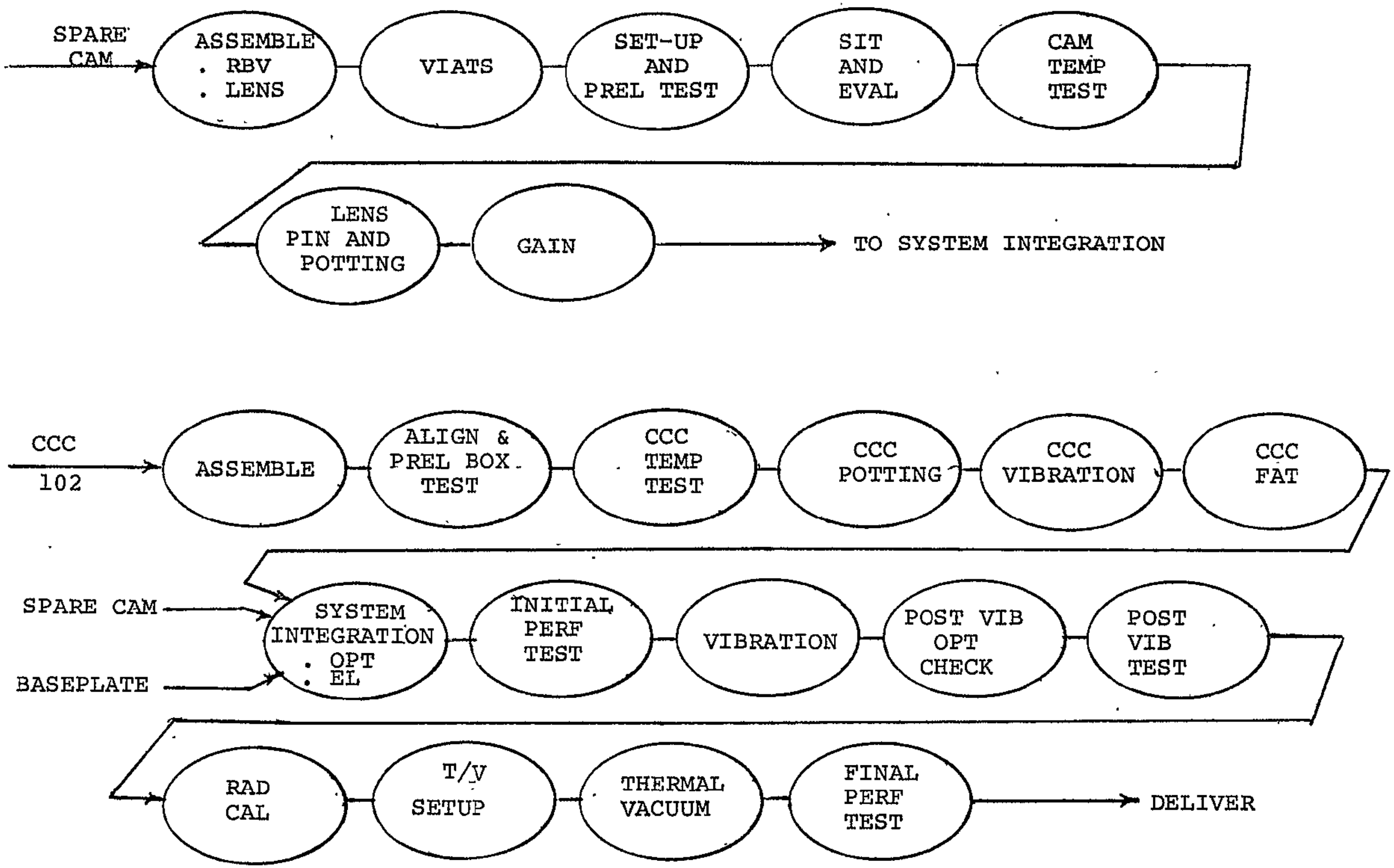


Figure IV-4. Landsat-C/RBV Spare Camera Test Flow

TABLE IV-17. PERFORMANCE SUMMARY
SPARE RBV CAMERA SYSTEM
FOR LANDSAT-C

CONTRACT PARAGRAPH	DESCRIPTION	SPEC VALUE	ACTUAL VALUE
3.3.1	Highlight Irradiance	2.013 MW/CM^2 - SR (505-750 nm)	Compliance
3.3.2	Camera Exposures	2.4; 4; 5.6; 8; 12 ms	Compliance
3.3.3(a)	Resolution - Center, Horizontal	4500 TVL	4521[1]
3.3.3(a)	Resolution - Center, Vertical	3500 TVL	>3403[1]
3.3.3(b)	Resolution - Edge, Horizontal	3600 TVL	3606[1]
3.3.3(b)	Resolution - Edge, Vertical	2800 TVL	>3403[1]
3.3.4	Signal-to-Noise Ratio	33 dB Min	30.3[1, 3]
3.3.5	Shading (Within 1" Circle)	15%	30.6% Max[1]
3.3.5	Shading (Overall)	25%	56.1% Max[1]
3.3.6	Image Distortion	< 1%	1.02% Horiz[1,3] 1.47% Vert[1, 3]
3.3.7	Aspect Ratio	1.1 Initially	99.77:1[1]
3.3.8	Size and Centering	< ±2%	< 1%
3.3.9	Residual Image	< 3%	< 0.5%[2]
3.4.4	Reticle Geometry	9 x 9 Array Sharply Defined	Compliance
3.4.9	Noise Susceptibility	Note 3	-
3.4.10	Electromagnetic Suscept	Note 3	-
3.4.13	Power Consumption	142 Watts Avg	System Total: 136 Watts Avg
3.6.1	Weight	System Total =170 Pounds	CCC = 10.11 Pounds Single Camera 60.93 Pounds

NOTES:
1. Taken from 20°C T/V data (March 29, 1977)
2. Center Region
3. Waiver requested.
4. EMI test not required on spare camera.

TABLE IV-18. LANDSAT-C/RBV SPARE HORIZONTAL MTF (CENTER RESOLUTION)

SPEC: 4500 TV LINES MIN

TVL	LP/MM	SPARE CAMERA (S/N 101) FINAL; AMB
2286	45	36.5
2794	55	22.8
2845	59	17.4
3403	67	12.9
4216	83	4.9
4521	89	2.8

TABLE IV-19. LANDSAT-C/RBV SPARE VERTICAL MTF (CENTER)

SPEC: 3500 TVL - 20° T/V

TVL	LP/MM	SPARE CAMERA RESPONSE
1778	35	76.4 %
2286	45	56.6 %
2743	54	39.8 %
2997	59	36.9 %
3403	67	25.6

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE IV-20. SHADING - LANDSAT-C/RBV FLIGHT
SPEC: 15% MAX WITHIN QUAL CIRCLE (CENTRAL)
25% MAX OVERALL (EDGE)

	DATA FROM QUALITY CIRCLE AREA			"EDGE" DATA		
	CAMERA 1 (S/N 102)	CAMERA 2 (S/N 103)	SPARE CAM	CAMERA 1 (S/N 102)	CAMERA 2 (S/N 103)	SPARE CAM
BLACK TOP (680)	8.6%	5.7%	9.9	9.3%	11.1	14.0
BLACK CENTER (2065)	6.8%	13.0%	10.0	6.8%	13.0	10.0
BLACK BOTTOM (3410)	7.5%	9.3%	20.8	16.5%	23.9	30.7
BLACK VERTICAL	3.1%	4.9%	3.9	3.1%	4.9	3.9
BLACK QUAL CIRCLE MAX	11.3%	13.9%	20.8	--	--	--
BLACK OVERALL MAX	--	--	--	29.2%	43.5%	56.1
WHITE TOP (680)	17.1%	12.2%	12.4	17.1%	12.2	25.2
WHITE CENTER (2065)	16.4%	6.6%	19.7	16.4%	6.6	19.7
WHITE BOTTOM (3410)	7.6%	5.0%	22.2	14.9	9.4	24.1
WHITE VERTICAL	11.2%	15.1%	13.3	11.2%	15.1	13.3
WHITE QUAL CIRCLE MAX	18.7	15.9%	30.6	--	--	
WHITE OVERALL MAX	--	--	--	29.0%	25.3	49.2

NOTE: DATA TAKEN AT 20°C T/V FROM CCC OUTPUT.

TABLE IV-21. LANDSAT-C/RBV SPARE
SIZE AND CENTERING CHANGES

	SPARE CAMERA (S/N 101)		
	30°C	20°C	10°C
VERTICAL SIZE	100.06%	100.12%	100.02%
VERTICAL CENTERING	+0.03%	+.02%	+0.06%
VERTICAL LINEARITY	1.53% [3]	1.47% [3]	1.49% [3]
ASPECT RATIO	1:1002	1:1002	1:1003
HORIZONTAL SIZE	99.82%	99.89%	99.71%
HORIZONTAL CENTERING	-0.23%	-0.17%	-0.34%
HORIZONTAL LINEARITY	1.04% [3]	1.02% [3]	-1.71% [3]
SKEW	1.20%	1.07%	1.29%

NOTES: 1) IN T/V, THE TEST CHART COULD NOT BE REMOVED CAUSING SEVERAL RETICLES TO BE UNDETECTED.

2) ALL DATA OBTAINED DURING T/V TEST.

3) ONE AREA ONLY.

TABLE IV-22. LANDSAT-C/RBV SPARE SIGNAL-TO-NOISE RATIO

	THERMAL VACUUM			AMBIENT
	30°C	20°C	10°C	FINAL
SPARE CAMERA S/N (DB)	30.0	30.3	30.8	31.1

<u>NOTE</u>: POST ACCEPTANCE TEST EVALUATION

OUTPUT BTE (A-SCOPE): 31.2 DB

OUTPUT BTE (COMPUTER): 31.2 DB

OUTPUT CCC (A-SCOPE): 33.1 DB

of the drift was not associated with the electronics but was involved with the vidicon characteristics. Readjustment of the target voltage controller threshold reduced the warm up drift by approximately one-half. This initial drift will not affect mission performance since actual scenes do not usually fill the dynamic range capability of the camera.

b. Variation in Horizontal Resolution in Thermal-Vacuum

During thermal-vacuum testing of the spare camera, S/N-101, a variation in horizontal resolution was noted. This condition was observed during constant temperature plateaus, thus eliminating any athermalization problem. At the conclusion of thermal-vacuum testing, the resolution variation was not observed during the final performance tests. Analysis of a video tape, made during a thermal vacuum test period when the resolution varied, showed the rise time across an RBV faceplate reticle to be constant, thus eliminating any electrical cause.

With the camera still mounted on the thermal vacuum fixture, the chamber's mechanical pumps were turned on. A variation in horizontal resolution was observed due to the slight vibrations transmitted to the camera equipment by the mechanical pumps. As soon as the pumps were turned off, the resolution variation ceased. Collimator movement was suspected since the collimator mount is not as stable as that for the camera, which is firmly bolted to its baseplate. The collimator was found to be capable of horizontal movement by slight finger pressure. In addition, a further review of the video tape (made during the resolution variation) showed a slight horizontal shift of the test pattern position when patterns from frames taken at different times were compared to the reticle positions. Based upon test results, it was concluded that the resolution variation observed in thermal vacuum was caused by horizontal movement of the collimator (with respect to the camera), induced by the chamber mechanical pumps.

SECTION V

STATUS OF EQUIPMENT (AS OF JUNE 1, 1977)

Flight Model (Cam 1, Cam 2, CCC 01, and Baseplate) - This subsystem has been integrated into the Landsat-C spacecraft and is currently being tested with other parts of the spacecraft.

Design Qualification Camera and the Spare Camera - These cameras are presently at RCA Astro-Electronics and will be tested every three months in order to ensure against performance degradation.

Camera Controller Combiner (CCC), Qualification Model and Spare Unit - These two CCC units are currently at RCA Astro-Electronics.

Ground Equipment at RCA Astro-Electronics - The following pieces of ground equipment are presently at RCA Astro-Electronics:

a) One Bench Test Equipment (BTE) unit, including console and test cart;

b) Three Special Test Equipment (STE) units including console and test cart (NOTE: one STE was NOT modified to the Landsat-C configuration);

c) Two computer racks and Teletype units;

d) One Quick Look Monitor (QLM);

e) One Vidicon Imaging Assembly Test Set (VIATS); and

f) One high speed tape reader and punch unit (for use with the computer units).

SECTION VI

RECOMMENDATIONS/GUIDELINES

A. Recommendations

1. Applications

The Return Beam Vidicon Camera was redesigned for the Landsat-C satellite to provide a higher ground resolution (40 meters) than that obtained using the Landsat 1&2 RBV cameras (80 meters). The advantage of this higher resolution capability was discussed with Dr. Robert McEwen (U.S. Geological Survey) who indicated two possible applications:

- An experiment is being planned to demonstrate the feasibility of combining the higher resolution pictures of the Landsat-C/RBV with the quality color pictures of the MSS in order to provide the "best of both worlds". This could become a forerunner of a comparable concept for future Landsat satellites. The higher resolution capability of RBV will be used to locate control points more accurately (e.g., highway intersections, etc.) Potentially, ground dimensioning should be about 4 times more accurate than previous MSS measurements. Based upon Landsat 1&2 experience with 1:250,000 scale pictures, the RBV smaller format size (53 nmi x 53 nmi), together with the accuracy of locating reseaus on the vidicon target ($\pm 3\mu M$), should lead to a geometric accuracy approaching that required for 1:100,000 scale maps, i.e., about 30 meter rms error. It should be noted that as a function of ground dimensions, the pixel size in the Landsat-C/RBV is about 21.8 meters (based upon 4500 TV lines high contrast limiting resolution) and the scan line pitch is about 23.8 meters (based upon 4125 active scan lines per frame.

- Another application for the RBV camera would be on the Synchronous Earth Observation Satellite (SEOS). The high resolution capability of the RBV makes it an ideal sensor to be used in conjunction with a telescope on board SEOS. As indicated in the SEOS Frame Camera Application Study Final Report (Reference D-1 of Section VII, Bibliography), the RBV could be used for observation of transient phenomena at any time, provided they fall within the fixed viewing circle of the spacecraft. On-going disasters could be monitored continuously, large areas of potential danger could be surveyed at any desired interval, and changing conditions of the Earth's resources could be observed at regular intervals.

2. Design

There are several design improvement areas which could be considered for future Landsat or SEOS missions; these include: image motion compensation; further shading improvements; elimination of the possibility of focus current regulator interference; and stero pictures.

a. Image Motion Compensation

It was recognized initially that smear effects due to spacecraft motion would be more critical for the Landsat-C/RBV than for the Landsat 1&2 RBV. However, it was decided that image motion compensation would not be required for the Landsat-C/RBV, since the MTF (including smear) was sufficiently great (about 70%) at 40 meters ground resolution for the nominal Landsat-C/RBV exposure of 5.6 milliseconds to justify this decision. If a further improvement in ground resolution were required (e.g., 30 meters) or if a significant increase in exposure time were needed, then image motion compensation should be utilized. Table VI-1 gives an example of the effect of smear on MTF. Shown is the MTF smear factor for 40 meter resolution and 30 meter resolution as a function of those exposure times selectable for the Landsat-C/RBV

TABLE VI-I. EFFECTS OF SMEAR ON MTF AS FUNCTION OF EXPOSURE

Exposure (Milliseconds)	Smear Component of MTF	
	40 Meter Gnd Res (48.31 lp/min)	30 Meter Gnd Res (64.42 lp/min)
2.4	93.2%	89.3%
4.0	83.6%	72.1%
5.6	69.5%	49.9%
8.0	44.1%	15.4%
12.0	3.0%	—

Note: Calculations based upon: Landsat C/RBV lens (236 millimeters EFL) and orbit altitude (492 nmi).

(Landsat C orbit parameters are assumed). Further information on image motion compensation can be obtained from the ERS Configuration Mission (Reference VII-B-3.) In addition, it should be noted that image motion compensation would not be needed for a SEOS mission RBV camera; there would be no significant relative motion between the SEOS satellite and the earth.

b. Shading

Two means of further reducing the RBV video shading are recommended; one is to redesign the thermal electric unit optical aperture so as to reduce vignetting, and the other is to develop a means of combining the vidicon target video with that of the anode video.

Shading at the corners of the raster, mesh transmission irregularities, and dynode imperfections are responsible for the bulk of the shading deficiencies in pictures produced by present RBV cameras which extract video from the vidicon anode. Most of these deficiencies are contained in the low frequency part of the video spectrum, perhaps below 100 kHz. The signal available from the

RBV target, while noisier than the anode signal for high frequency components of video, is virtually free of the above deficiencies. It appears that a further improvement in the subjective signal quality may be obtained by combining the two signals to obtain the advantages of each. As further discussed in the ERS Operational Mission Study Report (Reference VII-B-3), an arrangement is recommended in which the low frequency part of the video would be obtained from the target, and the high frequency part from the anode.

c. Focus Regulation Design

To eliminate the possibility of focus current regulator interference would require changing the design from that of a pulse width modulated type to a series regulator type. The pulse width modulated type generates spikes during switching intervals, and it is extremely difficult to sufficiently minimize the effect of these spikes in the video so that they cannot be seen in pictures. The increase in power caused by changing to a series regulator, would not be significant enough in this case to override the advantage of eliminating the interfering noise spikes.

d. Stereo Operation

Photographs of surface scenes from high flying platforms are usually analyzed for two purposes:

1) To determine the contents of the scene, and

2) To determine the locations of elements within the scene.

A pair of photographs taken in steroscopic fashion will readily facilitate both types of analysis. One can recognize items more easily if they are seen "in three dimensions" than if they are viewed in two dimensions. Stereo pictures are also very useful

for location and distance measurements; although horizontal distances on the earth can be measured relatively accurately with a single picture, elevation measurements can most easily be made with a pair of pictures. For unmapped regions or very rough terrain, the contours and elevation measurements that could be obtained from these systems, would be very useful. As indicated in the ERS Study Report (Reference VIII-B-3), a stereo RBV system could be produced by adding two additional cameras to the Landsat-C/RBV configuration (total of four cameras); the additional cameras would be pointed approximately 20° from the vertical. This concept is discussed in more detail in the aforementioned ERS report.

B. Guidelines

1. General

The Two-Camera Subsystem is designed to operate unattended during the life of the Landsat mission. The period during which the subsystem operates on a day-to-day basis and the selected modes of operation are determined by command signals, which are generated by an on-board storage unit or by the ground station. The required commands are listed in Table II-5. These commands are the only means of controlling the subsystem; there are no provisions for making further adjustments once it has left the manufacturer's plant. In addition, a series of telemetry points is used to monitor the operation of various parts of the subsystem; these points are sampled at regular intervals by the spacecraft telemetry unit and the resulting information is transmitted to the receiving site. A list of subsystem telemetry points is given in Table II-6. For special testing of the subsystem prior to final spacecraft integration, there are a series of test points that can be used for determining circuit status or for metering subsystem components without requiring disassembly. These test points are provided with short-circuit protection.

2. Precautions

Several precautions are necessary for operating the subsystem, as follows:

- Signal, power, and command amplitudes must be as specified prior to energizing the subsystem;
- ON commands for the CCC and the cameras should be issued within ten seconds of each other, so that each of the cameras to be energized may enter and remain in the Warmup mode for a major part of the 50 seconds. The Warmup interval starts when the first camera or the CCC is energized;
- Lens caps must be removed prior to launch;
- Cameras should not be commanded into the Cathode Reactivation mode unless it is positively determined to be necessary by personnel familiar with the equipment; and
- The CCC must always be energized prior to turning on the cameras.

3. Operational Evauation

Prior to spacecraft integration, the operation of the subsystem should be evaluated at three-month intervals. If the resulting performance data conforms to the manufacturer's acceptance test data, the system is operating properly. If there are discrepancies, the proper operation of various parts of the subsystem can be verified (without opening any component) by using the available telemetry points (Tabe II-6) and test points; any further diagnosis should be performed only under the direction of an engineer intimately familiar with the subsystem. Equipment that has been integrated with the spacecraft should also be checked operationally at least every three months.

4. Lens Cleaning

If required, the lens should be cleaned in accordance with the Cleaning and Handling Procedure, RCA-CHP-2284900.

SECTION VII
BIBLIOGRAPHY

A. NASA/GSFC DOCUMENTS

1. GSFC 430-C-290A; Landsat-C Two Camera Return Beam Vidicon (RBV) System and Associated Equipment.

2. GSFC 430-C-310; Environmental Test Specification for Landsat-C Observatory Systems and Sensors.

B. RCA LANDSAT 1&2 DOCUMENTS (PRODUCED FOR NASA/GSFC BY RCA ASTRO-ELECTRONICS UNDER CONTRACT NAS 5-21904)

1. Operations and Maintenance Manual for the RBV Multi-spectral Three-Camera Subsystem for ERTS A&B; AED #M-8012F; Issued September, 1972.

2. Combined Final Report for the Return Beam Vidicon Multispectral Three-Camera Subsystem for ERTS A&B; AED-R-4069; Issued December 2, 1974.

3. Configuration and Performance; Return Beam Vidicon Camera Systems for the ERS Operational Mission; AED R-3950; Issued July 31, 1973.

C. RCA LANDSAT-C DOCUMENTS (PREPARED FOR NASA/GSFC BY RCA ASTRO-ELECTRONICS UNDER CONTRACT NAS 5-22350

1. Two Camera RBV System Performance Specification (RCA PS-2284900).

2. CCC Performance Specification (RCA PS-2284903).

3. Critical Design Review; Return Beam Vidicon Camera System; AED-R-4129; Issued November 6, 1975.

4. Operational and Maintenance Manual for the Return Beam Vidicon Bench Test Equipment Modified for Dual 2&3 Camera Operation; AED R-2178; July, 1976.

5. Stage Release System Information; Stage 4 (Final); Issued September 1, 1976.

6. Design Concept Review Package, Return Beam Vidicon Camera System for Landsat-C; prepared by RCA Astro-Electronics, Princeton, N.J., for NASA/GSFC, Greenbelt, Maryland; Issued May 20, 1975.

7. Exposure Analysis and Recommendations for Landsat-C/RBV prepared for NASA/GSFC, Greenbelt, Maryland by RCA Astro-Electronics, Princeton, N.J., under contract NAS 5-22350; Issued September, 1976.

8. GSE Design Modification Report, prepared for NASA/GSFC Greenbelt, Maryland by RCA Astro-Electronics, Princeton, N.J., under contract NAS 5-22350 (Landsat-C/RBV).

D. OTHER RCA DOCUMENTS

1. Final Report; SEOS Frame Camera Application Study; prepared for NASA-GSFC by RCA Astro-Electronics under contract NAS5-21989; AED R-4045; issued Nov. 14, 1974.

E. LANDSAT-C/RBV PLANNING DIAGRAM

1. This planning diagram lists all of the schematic and assembly drawings for the Landsat-C/RBV; it is shown as Figure VII-1.

FOLDOUT FRAME 2

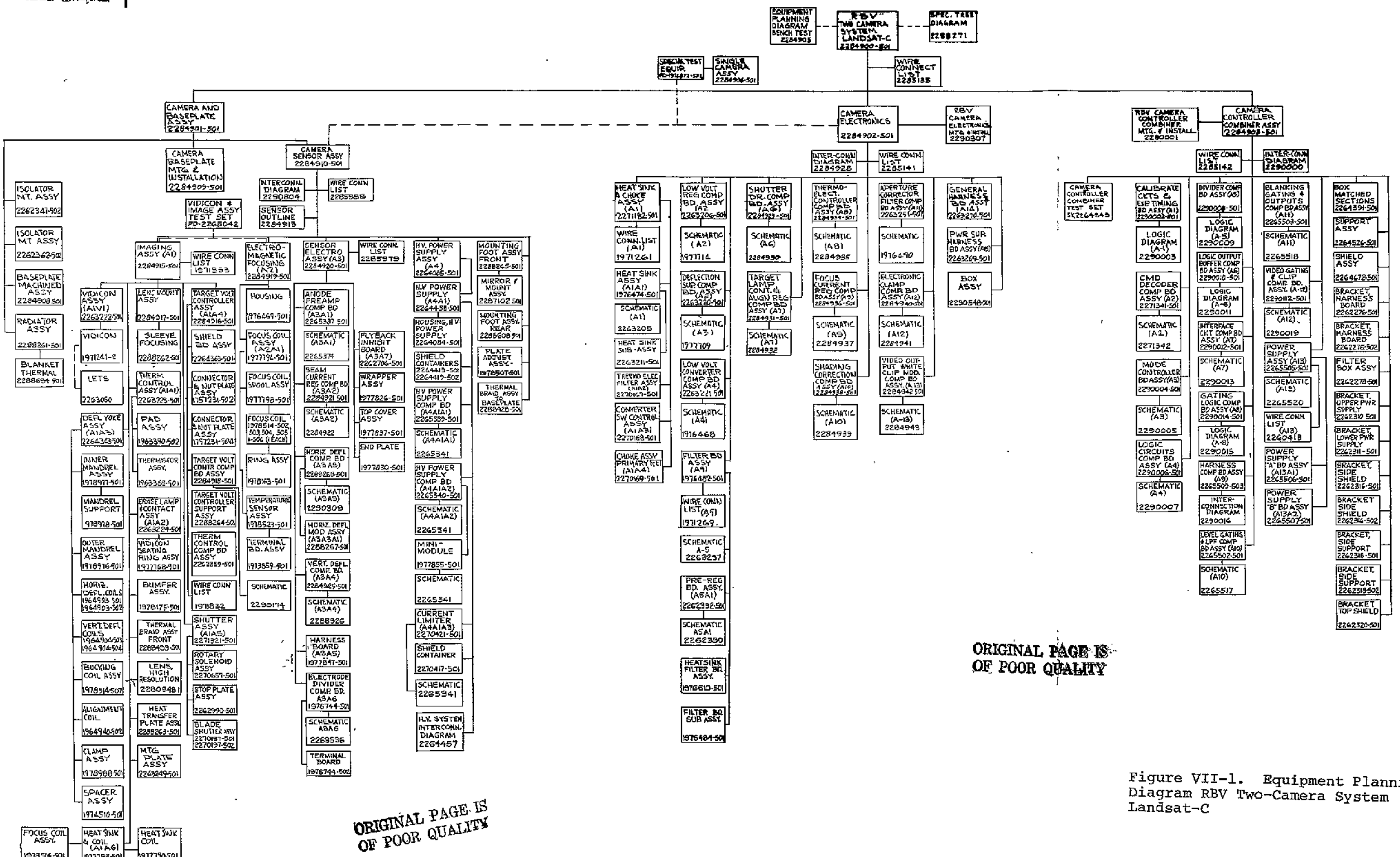


Figure VII-1. Equipment Planning Diagram RBV Two-Camera System Landsat-C

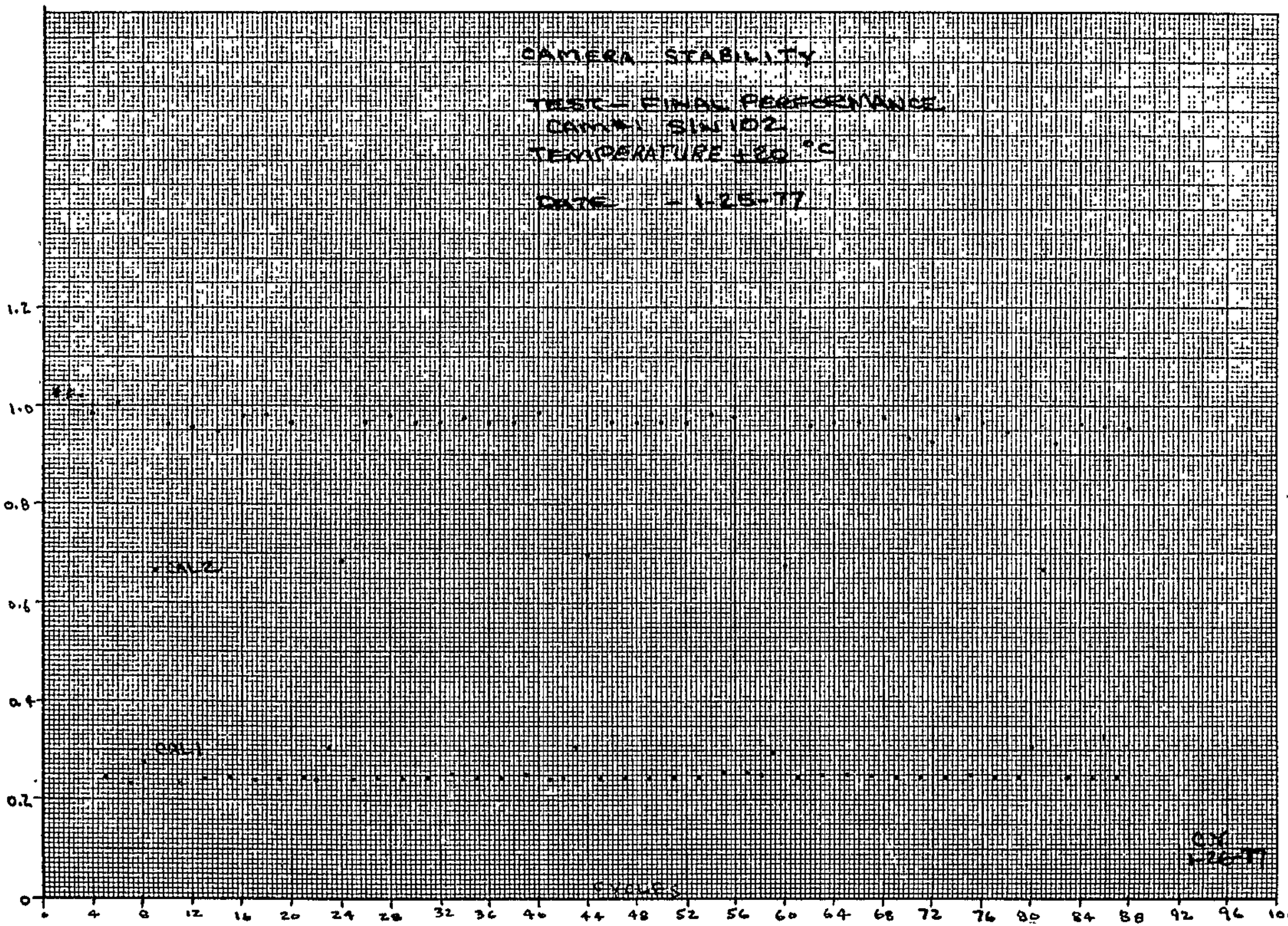
APPENDIX A

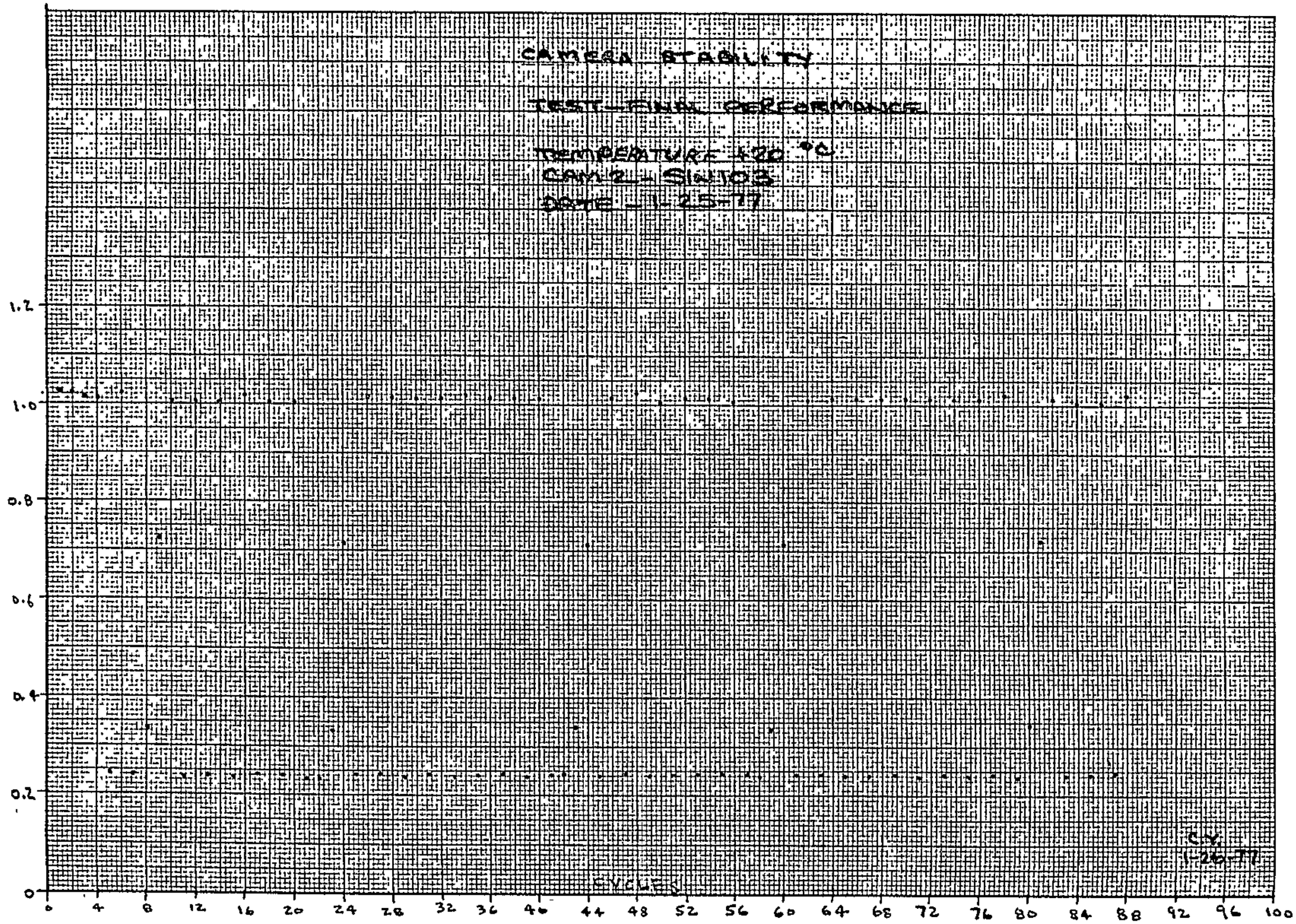
CALIBRATION DATA

SECTION I:	CAMERA STABILITY
SECTION II:	CAMERA LIGHT TRANSFER CHARACTERISTICS
SECTION III:	RESEAU POSITIONS
SECTION IV:	ANALOG TELEMETRY CHARACTERISTICS

SECTION I

CAMERA STABILITY


CAMERA STABILITY
TEST - FINAL PERFORMANCE
CAMERA S/N 102
TEMPERATURE +20 °C
DATE - 1-25-77
CAL 2
CAL 1
CYCLES
0
0.2
0.4
0.6
0.8
1.0
1.2
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100


CAMERA STABILITY
TEST—FINAL PERFORMANCE
TEMPERATURE +20 °C
CAM 2 - S/N 103
DATE - 1-25-77
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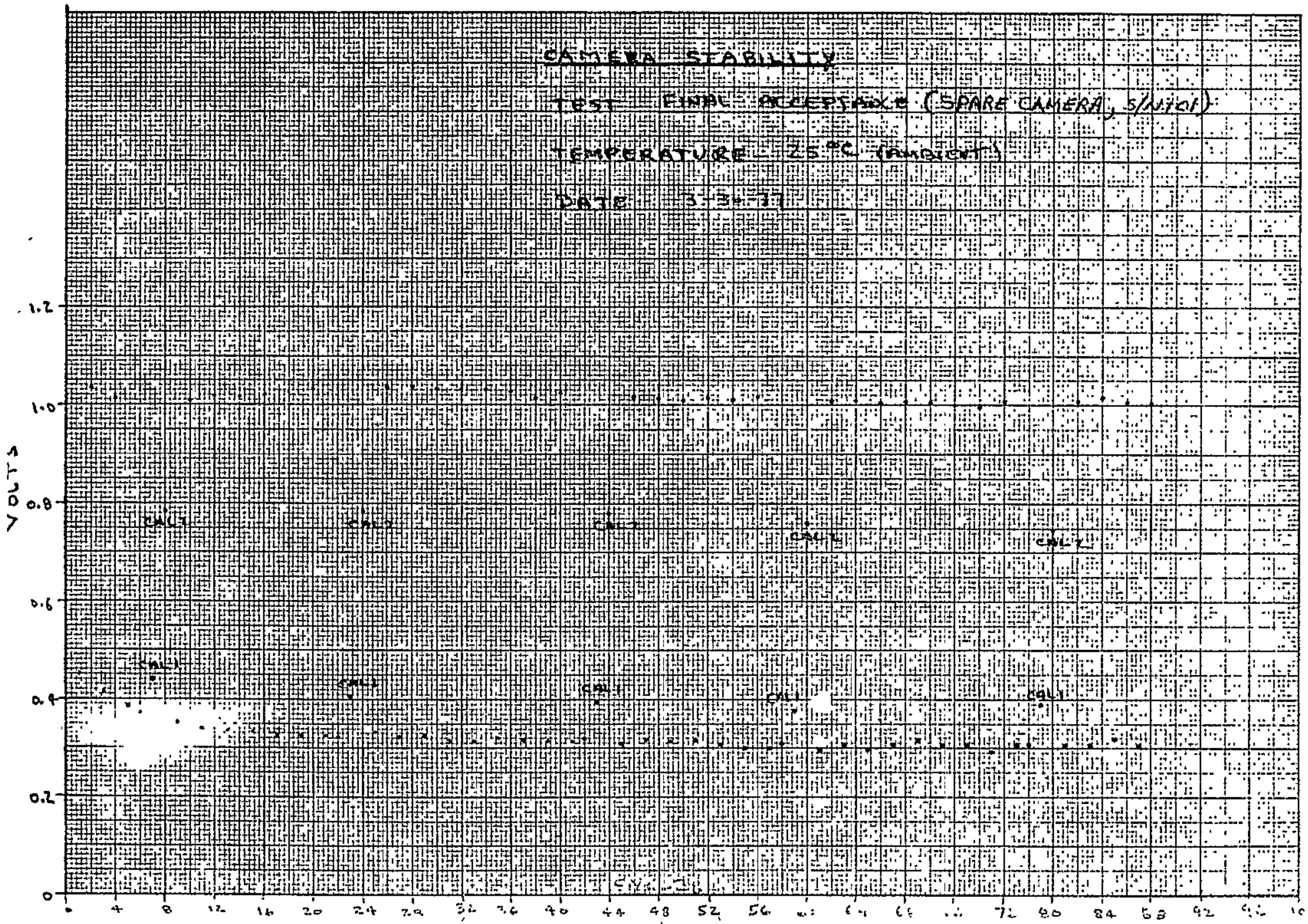
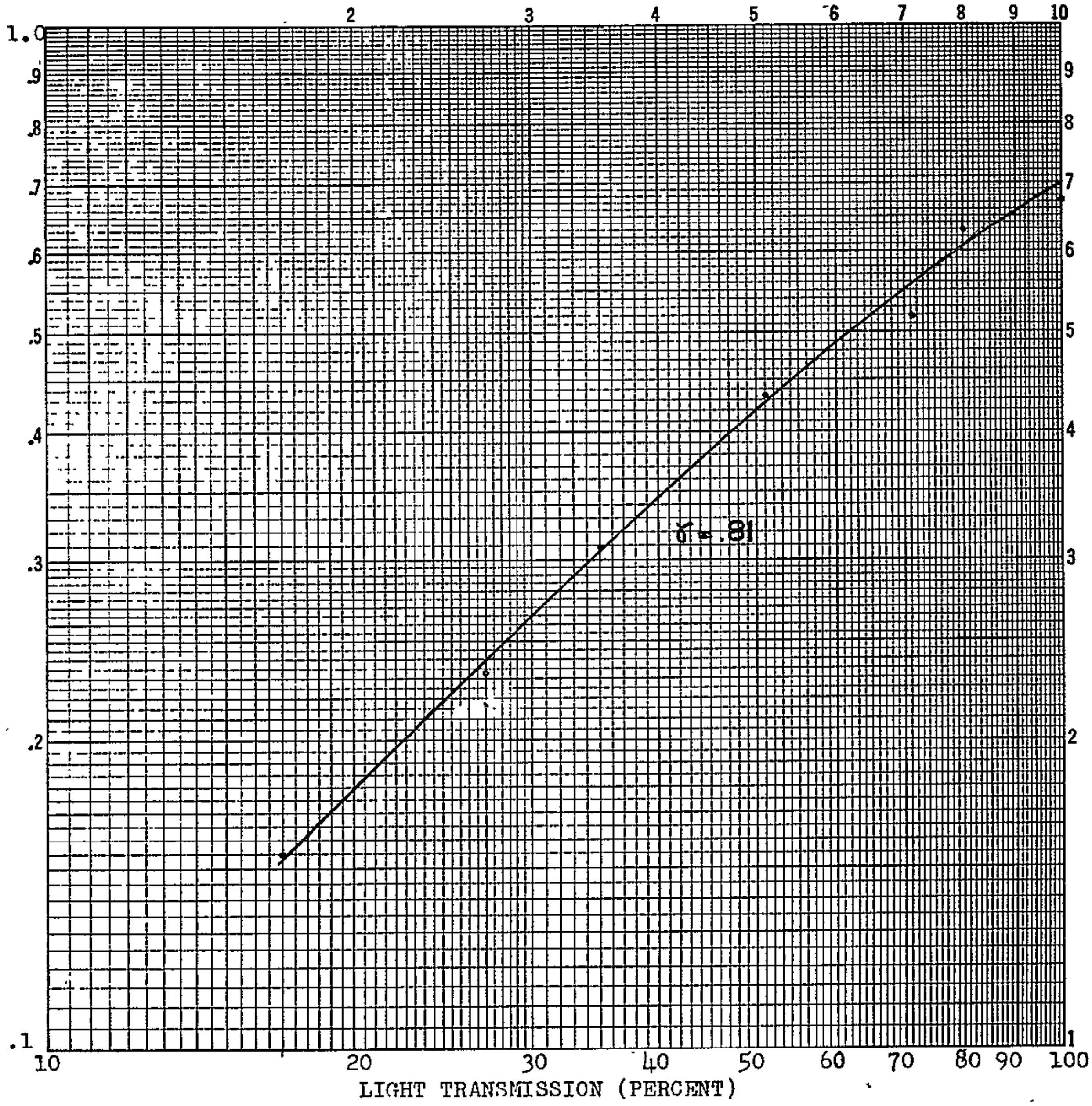
1.0
0.8
0.6
0.4
0.2
0
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100
CYCLES
C.Y.
1-26-77


CAMERA STABILITY
TEST FINAL ACCEPTANCE (SPARE CAMERA, S/N101)
TEMPERATURE 25°C (AMBIENT)
VOLTS
CAL 1
CAL 2
0
0.2
0.4
0.6
0.8
1.0
1.2
4
8
12
16
20
24
28
32
36
40
44
48
52
56
72
80
84
88
92
100

SECTION II

CAMERA LIGHT TRANSFER CHARACTERISTICS

Camera 1 (S/N102)
Final Performance Test
1-24-77



Camera 2 (S/N103)
Final Performance Test
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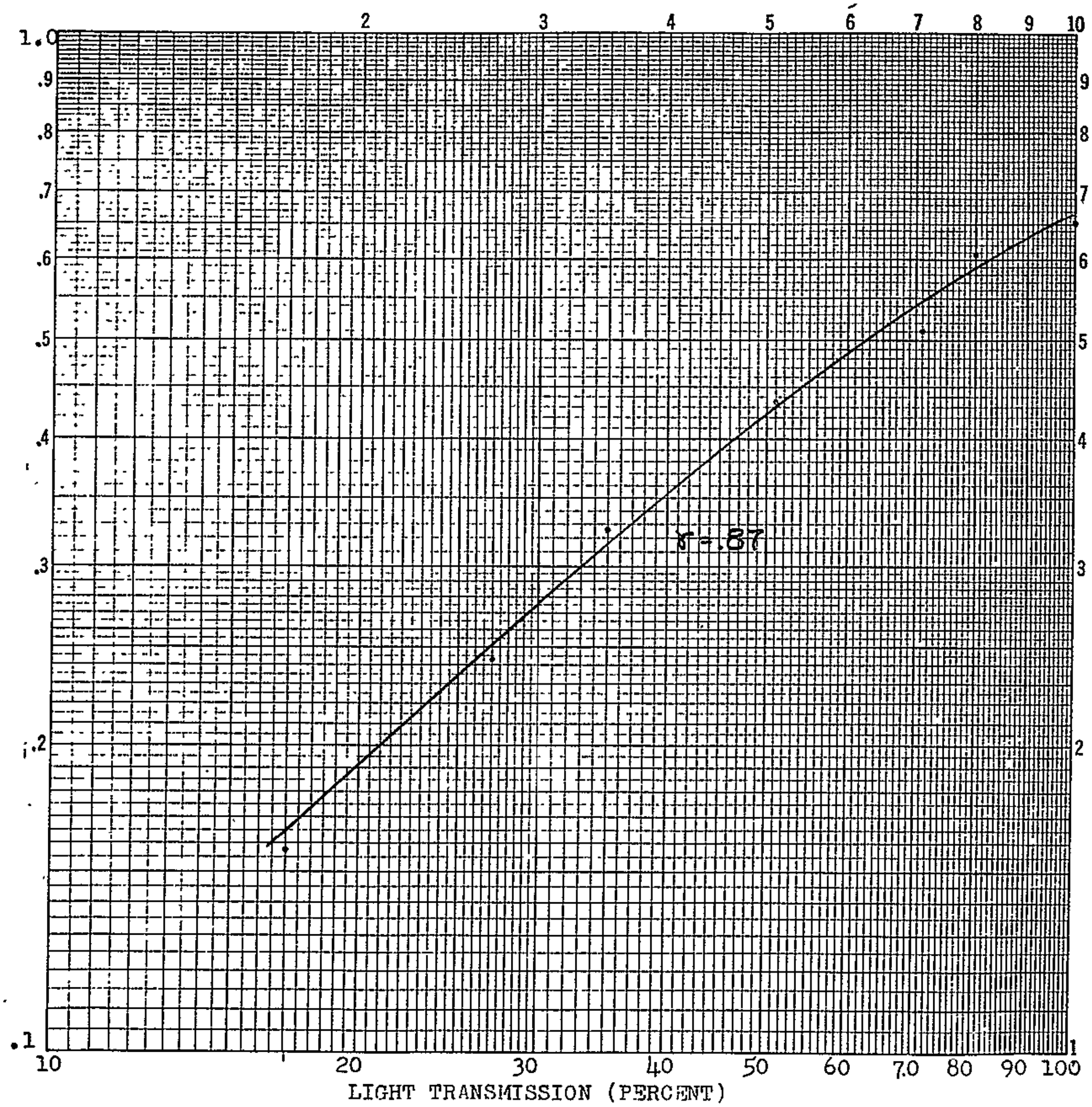
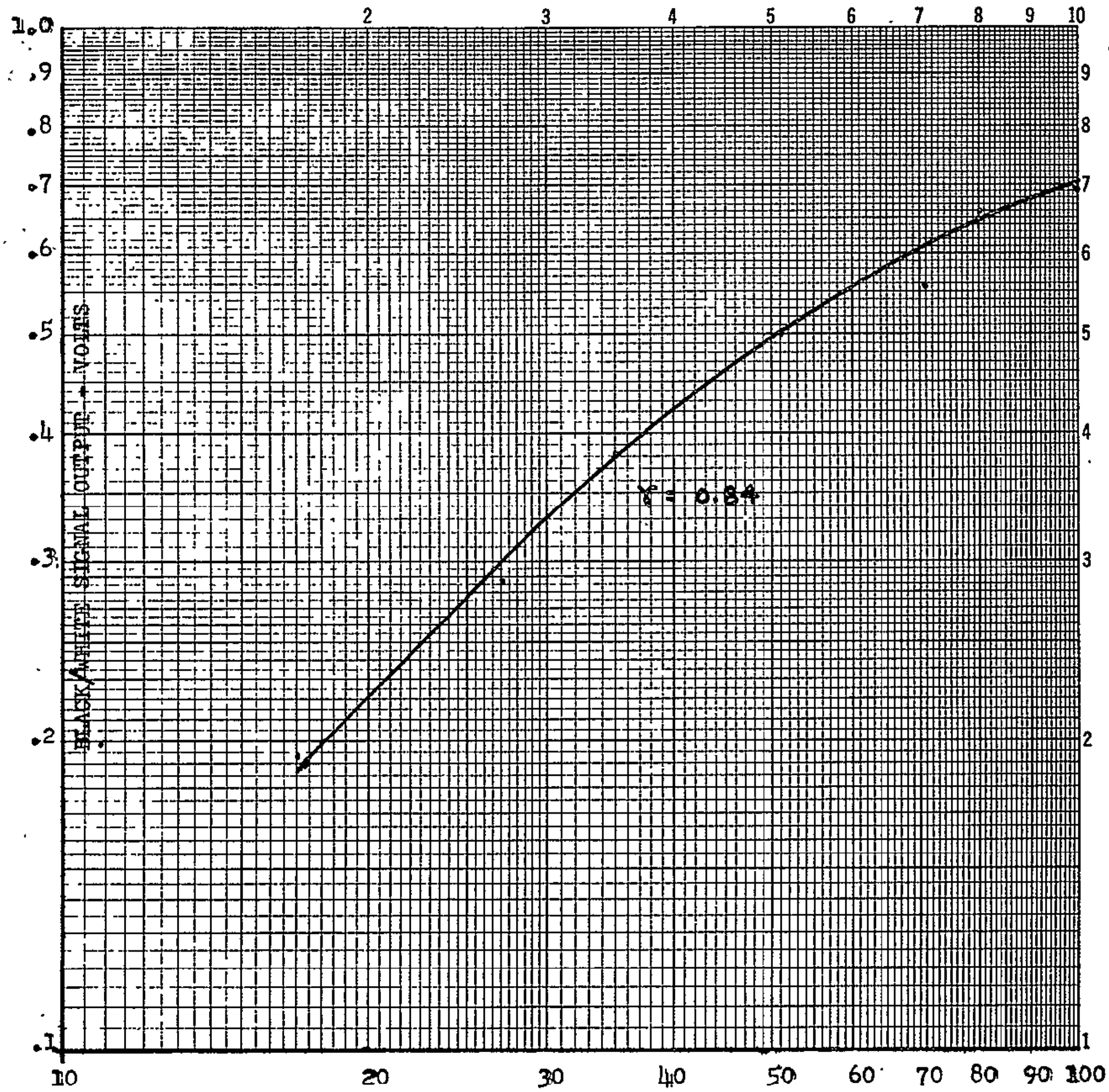


SPARE CAMERA (S/N 101)
3-15-77



LIGHT TRANSMISSION - PERCENT

SECTION III

RCA RETURN BEAM VIDICON (RBV) RESEAU COORDINATES FOR LANDSAT-C

RBV #S19917 (Spare Vidicon; data not incl.)
RBV #S19930 (Camera #1, S/N 102, RBV)
RBV #S19931 (Camera #2, S/N 103, RBV)
RBV #S19944 (Spare Cam. RBV)

Topographic Division
U.S. Georgraphical Survey
National Center
12201 Sunrise Valley Drive
Reston, VA 22092

March, 1976

I. PURPOSE

The purpose of this report is to distribute the results of the reseau measurements for the four RCA Return Beam Vidicon (RBV) tubes under consideration for use in Landsat-C.

II. BRIEF DESCRIPTION OF METHOD

The method used for reseau measurement includes adaptation of a coordinate system, a measurement technique, and a coordinate adjustment.

A. Coordinate System (See Figure 1)

An orthogonal right hand coordinate system with origin at the rear nodal point of the lens has been adopted for the RBV camera. The positive X axis is directed from the nodal point toward the RBV faceplate upon which the reseau is etched. In the reseau plane point number 55 is assigned coordinates of 0,0. The positive X axis is directed through point number 59. The matrix of 81 reseau points have been given numbers in an X-Y row-column sequence. Point number 11 has the largest negative X and Y values. There are four anchor points outside the reseau pattern which have been given numbesr 195, 11, 151, and 159. The last two digits correspond with the closest reseau point. Anchor points 115 and 151 each have a distinctive pattern; anchor points 159 and 195 have the same pattern. The direction of the orbit and the H-V coordinate system used to designate the horizontal and vertical direction of the TV scan lines are shown. Each scan line is in the H-direction with successive scan lines in the V-direction.

B. Measurement Technique (See Figure 2)

The RBV is placed faceplate up in a mounting bracket on the stage of a Mann mono comparator. Above the tube is an auxiliary set of optics with crosshairs for centering the reseaux. A small

lamp and beamsplitter are used to illuminate the reseaux. Four sets of readings are taken on each tube using at least two or three observers requiring that two sets be taken by the same observer. During measurement a continual check is maintained against gross errors. Since the reseau format is only one inch, it is not believed necessary to perform comparator calibration or temperature corrections. The Mann mono comparator reads directly to 1 micrometre which is within the accuracy required.

C. Coordinate Adjustment

The coordinate data is reduced after an initial translation and rotation to reseau points number 55 and 59. Additional readings (five per set) on these two points are obtained for this purpose. The mean coordinate values for each point are computed. Several statistics are computed including the standard deviation of four observations at each point and for each observer on all points of a set. A check for bias of an observer is also performed. Finally, the displacements between nominal position and measured position of each point are computed. The nominal positions are based on a 2.800 mm spacing between reseaux. A large scale plot of the nominal positions, mean measured position, and the four sets of readings is made on the IBM 1627 plotter. A best fit of the measured positions to the nominal positions is not performed. Rather, the effort has been directed toward obtaining a uniform set of coordinates with origin at point number 55 and positive X axis directed toward point number 59.

III. ACCURACY OF RESULTS

The purpose of the measurement program is to determine the reseau coordinates to an absolute accuracy of ± 3 micrometres or better. The standard deviation for each point and each observer are generally below 2 micrometres. A very few points have standard deviations of 3 or 4 micrometres. This is attributed to an unequal or uneven line width on a few reseaux. The mean

measured position of all reseaux have an accuracy close to ±2 micrometres. This more than satisfies the 3 micrometre goal.

IV. RBV TUBES MEASURED

The number and date of measurement of the RBV tubes covered by this report are as follows:

RBV Number	Date
S19917[1]	November 6, 1972
S19930 (Cam. 1)	November 30, 1972
S19931 (Cam. 2)	March 2, 1976
S19944	March 2, 1976

Note 1. Data not included

V. RESEAU COORDINATES

The reseau coordinates are given in the following pages. A copy of the IBM 1627 plotter output, as well as additional copies of this report are available upon request from:

Remote Sensors & Space Applications Team
Branch of Photogrammetry
USGS National Center (510)
Reston, VA 22092

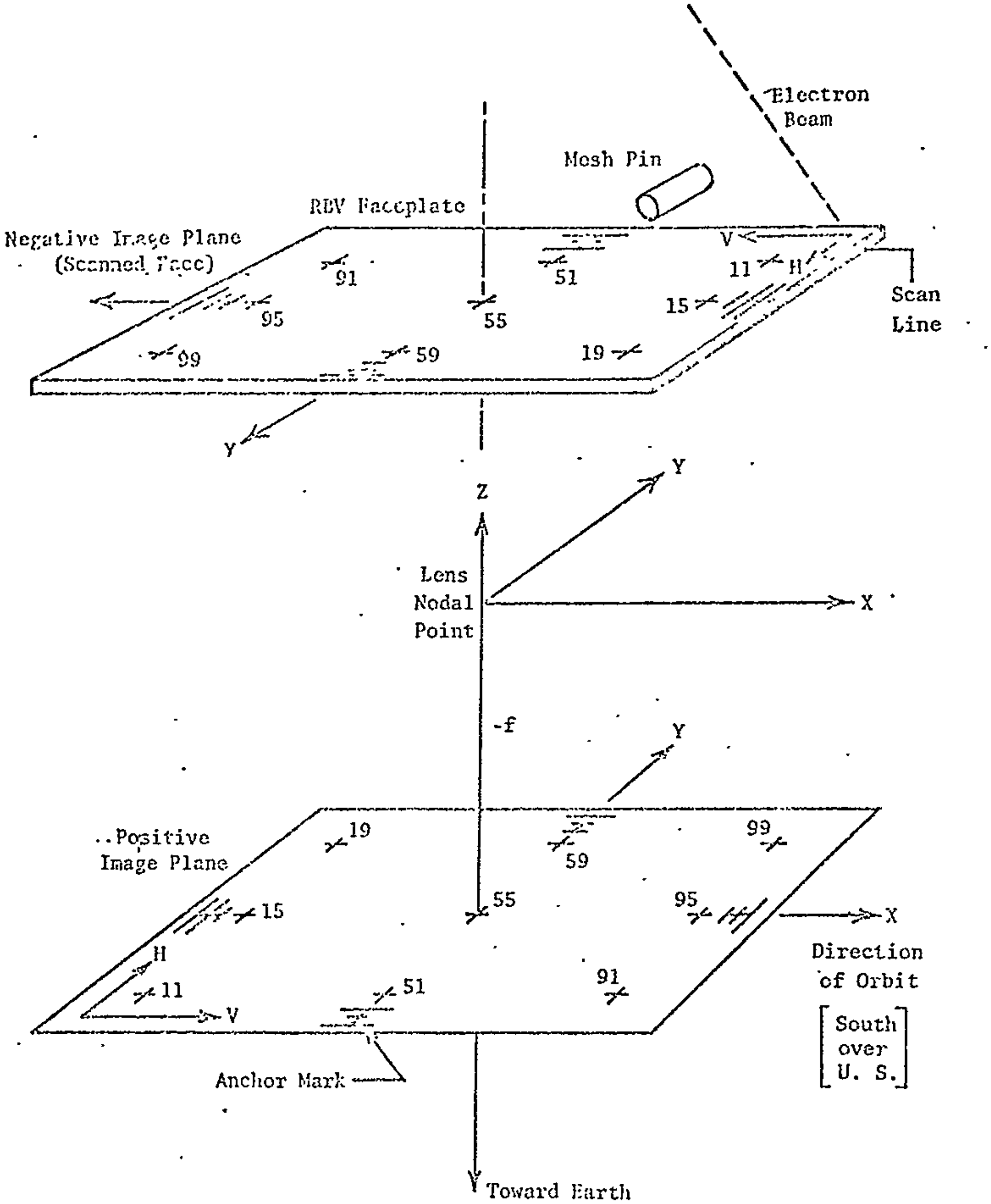


Figure 1. RBV Coordinate System

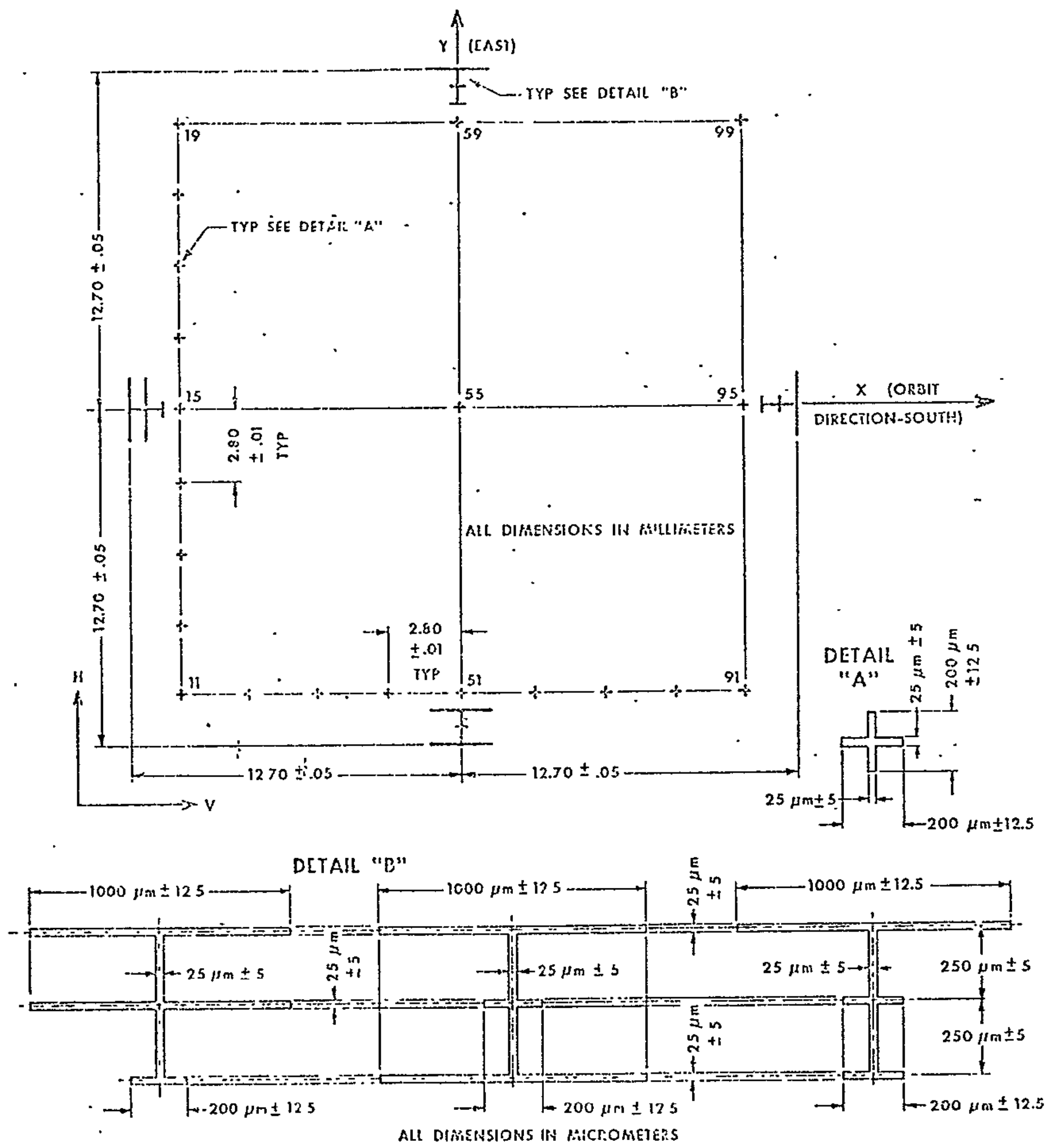


Figure 2. RBV Reseau Pattern

REDUCTION OF RBV RESEAU MEASUREMENTS

CALIBRATION OF RCA - RBV S19930* 20 NOVEMBER 1972

MEAN POSITIONS OF RESEAU MARKS (Millimeters)

POINT NO.	NOMINAL POSITION X	Y	MEAN POSITION X	Y	DISPLACEMENTS FROM NOMINAL X	Y
11	-11.200	-11.200	-11.187	-11.204	0.0124	-0.0047
12	-11.200	-8.400	-11.188	-8.408	0.0119	-0.0087
13	-11.200	-5.600	-11.188	-5.606	0.0117	-0.0064
14	-11.200	-2.800	-11.187	-2.801	0.0129	-0.0019
15	-11.200	0.000	-11.186	-0.000	0.0137	-0.0009
16	-11.200	2.800	-11.186	2.802	0.0132	0.0027
17	-11.200	5.600	-11.185	5.600	0.0149	0.0007
18	-11.200	8.400	-11.184	8.401	0.0159	0.0010
19	-11.200	11.200	-11.185	11.204	0.0142	0.0047
29	-8.400	11.200	-8.384	11.204	0.0152	0.0045
28	-8.400	8.400	-8.386	8.401	0.0139	0.0012
27	-8.400	5.600	-8.385	5.599	0.0144	-0.0004
26	-8.400	2.800	-8.386	2.798	0.0137	-0.0019
25	-8.400	0.000	-8.387	-0.000	0.0122	-0.0009
24	-8.400	-2.800	-8.388	-2.803	0.0117	-0.0032
23	-8.400	-5.600	-8.388	-5.603	0.0112	-0.0039
22	-8.400	-8.400	-8.388	-8.408	0.0114	-0.0087
21	-8.400	-11.200	-8.388	-11.204	0.0117	-0.0049
31	-5.600	-11.200	-5.586	-11.203	0.0139	-0.0039
32	-5.600	-8.400	-5.586	-8.407	0.0137	-0.0072
33	-5.600	-5.600	-5.588	-5.602	0.0117	-0.0029
34	-5.600	-2.800	-5.587	-2.802	0.0127	-0.0029
35	-5.600	0.000	-5.587	-0.000	0.0127	-0.0009
36	-5.600	2.800	-5.586	2.797	0.0132	-0.0027
37	-5.600	5.600	-5.586	5.599	0.0137	-0.0002
38	-5.600	8.400	-5.585	8.400	0.0142	0.0000
39	-5.600	11.200	-5.586	11.205	0.0132	0.0057
49	-2.800	11.200	-2.783	11.206	0.0164	0.0060
48	-2.800	8.400	-2.783	8.401	0.0169	0.0012
47	-2.800	5.600	-2.785	5.599	0.0149	-0.0009
46	-2.800	2.800	-2.786	2.798	0.0137	-0.0019
45	-2.800	0.000	-2.786	-0.000	0.0137	-0.0007
44	-2.800	-2.800	-2.786	-2.801	0.0134	-0.0014
43	-2.800	-5.600	-2.788	-5.602	0.0119	-0.0024
42	-2.800	-8.400	-2.787	-8.406	0.0129	-0.0069
41	-2.800	-11.200	-2.788	-11.204	0.0119	-0.0042
51	0.000	-11.200	0.002	-11.202	0.0020	-0.0027
52	0.000	-8.400	0.001	-8.406	0.0015	-0.0062
53	0.000	-5.600	0.000	-5.601	0.0005	-0.0017
54	0.000	-2.800	0.000	-2.801	0.0007	-0.0014
55	0.000	0.000	-0.000	0.000	-0.0000	0.0000
56	0.000	2.800	-0.000	2.798	-0.0002	-0.0014
57	0.000	5.600	-0.000	5.600	-0.0005	0.0000
58	0.000	8.400	0.001	8.400	0.0015	0.0007
59	0.000	11.200	-0.000	11.201	-0.0007	0.0017
69	2.800	11.200	2.806	11.203	0.0067	0.0030
68	2.800	8.400	2.808	8.400	0.0082	0.0005
67	2.800	5.600	2.805	5.599	0.0057	-0.0004

66	2.800	2.800	2.806	2.798	0.0067	-0.0014
65	2.800	0.000	2.805	-0.000	0.0057	-0.0007
64	2.800	-2.800	2.806	-2.801	0.0055	-0.0017
63	2.800	-5.600	2.805	-5.602	0.0050	-0.0024
62	2.800	-8.400	2.804	-8.406	0.0047	-0.0062
61	2.800	-11.200	2.805	-11.205	0.0055	-0.0057
71	5.600	-11.200	5.607	-11.204	0.0072	-0.0046
72	5.600	-8.400	5.604	-8.403	0.0047	-0.0032
73	5.600	-5.600	5.606	-5.602	0.0062	-0.0027
74	5.600	-2.800	5.606	-2.800	0.0060	-0.0009
75	5.600	0.000	5.605	0.000	0.0057	0.0000
76	5.600	2.800	5.606	2.800	0.0062	0.0002
77	5.600	5.600	5.606	5.600	0.0065	0.0000
78	5.600	8.400	5.606	8.402	0.0062	0.0025
79	5.600	11.200	5.605	11.203	0.0052	0.0025
89	8.400	11.200	8.401	11.203	0.0015	0.0035
88	8.400	8.400	8.402	8.401	0.0027	0.0012
87	8.400	5.600	8.400	5.599	0.0005	-0.0006
86	8.400	2.800	8.400	2.799	0.0002	-0.0009
85	8.400	0.000	8.410	-0.000	0.0105	-0.0004
84	8.400	-2.800	8.410	-2.800	0.0102	-0.0002
83	8.400	-5.600	8.407	-5.600	0.0075	-0.0009
82	8.400	-8.400	8.409	-8.404	0.0092	-0.0047
81	8.400	-11.200	8.410	-11.204	0.0106	-0.0044
91	11.200	-11.200	11.204	-11.203	0.0045	-0.0037
92	11.200	-8.400	11.201	-8.405	0.0012	-0.0054
93	11.200	-5.600	11.202	-5.600	0.0022	-0.0007
94	11.200	-2.800	11.201	-2.801	0.0015	-0.0012
95	11.200	0.000	11.201	0.000	0.0010	0.0000
96	11.200	2.800	11.201	2.799	0.0010	-0.0009
97	11.200	5.600	11.199	5.600	-0.0002	0.0005
98	11.200	8.400	11.201	8.403	0.0015	0.0026
99	11.200	11.200	11.200	11.201	0.0010	0.0017
195	12.450	0.000	12.463	-0.001	0.0137	-0.0007
115	-12.450	0.000	-12.429	-0.002	0.0209	-0.0022
151	0.000	-12.450	0.005	-12.458	0.0057	-0.0084
159	0.000	12.450	0.004	12.448	0.0042	-0.0012

CALIBRATION OF RCA - RBV S19920* 30 NOVEMBER 1972

*used in Camera 1, S/N 102

ORIGINAL PAGE IS
OF POOR QUALITY

REDUCTION OF RBV RESEAU MEASUREMENTS

CALIBRATION OF RCA-RBV S19931** MARCH 2, 1976

MEAN POSITIONS OF RESEAU MARKS (Millimeters)

POINT	NOMINAL POSITION		MEAN POSITION		DISPLACEMENTS FROM NOMINAL	
NO.	X	Y	X	Y	X	Y
11	-11.200	-11.200	-11.199	-11.205	0.0107	-0.0056
12	-11.200	-8.400	-11.189	-8.406	0.0106	-0.0062
13	-11.200	-5.600	-11.189	-5.605	0.0109	-0.0050
14	-11.200	-2.800	-11.188	-2.804	0.0113	-0.0046
15	-11.200	0.000	-11.189	-0.004	0.0108	-0.0042
16	-11.200	2.800	-11.189	2.800	0.0107	0.0005
17	-11.200	5.600	-11.187	5.598	0.0120	-0.0018
18	-11.200	8.400	-11.188	8.397	0.0119	-0.0021
19	-11.200	11.200	-11.188	11.198	0.0116	-0.0016
29	-8.400	11.200	-8.389	11.201	0.0104	0.0011
28	-8.400	8.400	-8.389	8.399	0.0102	-0.0005
27	-8.400	5.600	-8.390	5.598	0.0097	-0.0012
26	-8.400	2.800	-8.389	2.797	0.0102	-0.0028
25	-8.400	0.000	-8.390	-0.003	0.0095	-0.0028
24	-8.400	-2.800	-8.389	-2.803	0.0106	-0.0030
23	-8.400	-5.600	-8.388	-5.603	0.0111	-0.0034
22	-8.400	-8.400	-8.389	-8.407	0.0101	-0.0073
21	-8.400	-11.200	-8.389	-11.203	0.0107	-0.0035
31	-5.600	-11.200	-5.589	-11.205	0.0107	-0.0050
32	-5.600	-8.400	-5.589	-8.406	0.0111	-0.0062
33	-5.600	-5.600	-5.590	-5.602	0.0099	-0.0021
34	-5.600	-2.800	-5.590	-2.805	0.0098	-0.0057
35	-5.600	0.000	-5.589	-0.003	0.0115	-0.0035
36	-5.600	2.800	-5.589	2.798	0.0100	-0.0010
37	-5.600	5.600	-5.589	5.599	0.0100	-0.0005
38	-5.600	8.400	-5.590	8.400	0.0097	0.0007
39	-5.600	11.200	-5.589	11.202	0.0106	0.0022
49	-2.800	11.200	-2.788	11.203	0.0119	0.0034
48	-2.800	8.400	-2.788	8.401	0.0119	0.0017
47	-2.800	5.600	-2.789	5.599	0.0107	-0.0000
46	-2.800	2.800	-2.789	2.798	0.0107	-0.0015
45	-2.800	0.000	-2.788	-0.005	0.0115	-0.0052
44	-2.800	-2.800	-2.788	-2.801	0.0116	-0.0012
43	-2.800	-5.600	-2.789	-5.600	0.0111	-0.0005
42	-2.800	-8.400	-2.788	-8.406	0.0119	-0.0060
41	-2.800	-11.200	-2.788	-11.203	0.0119	-0.0032
51	0.000	-11.200	0.000	-11.207	0.0009	-0.0077
52	0.000	-8.400	0.000	-8.404	0.0004	-0.0044
53	0.000	-5.600	0.000	-5.600	0.0004	-0.0009
54	0.000	-2.800	0.000	-2.800	0.0006	-0.0009
55	0.000	0.000	0.000	-0.000	0.0003	-0.0002
56	0.000	2.800	0.000	2.800	0.0005	0.0000
57	0.000	5.600	0.000	5.600	0.0002	0.0000
58	0.000	8.400	0.000	8.401	0.0009	0.0012
59	0.000	11.200	0.000	11.202	0.0004	0.0027
69	2.800	11.200	2.807	11.203	0.0076	0.0038
68	2.800	8.400	2.807	8.402	0.0079	0.0023
67	2.800	5.600	2.808	5.600	0.0080	0.0003

66	2.800	2.800	2.807	2.800	0.0077	0.0002
65	2.800	0.000	2.808	-0.001	0.0080	-0.0011
64	2.800	-2.800	2.808	-2.800	0.0051	-0.0004
63	2.800	-5.600	2.807	-5.601	0.0074	-0.0011
62	2.800	-8.400	2.808	-8.404	0.0084	-0.0042
61	2.800	-11.200	2.809	-11.204	0.0094	-0.0044
71	5.600	-11.200	5.607	-11.203	0.0079	-0.0031
72	5.600	-8.400	5.606	-8.403	0.0061	-0.0031
73	5.600	-5.600	5.605	-5.599	0.0056	0.0006
74	5.600	-2.800	5.606	-2.801	0.0063	-0.0016
75	5.600	0.000	5.606	-0.000	0.0060	-0.0003
76	5.600	2.800	5.605	2.801	0.0055	0.0013
77	5.600	5.600	5.605	5.601	0.0055	0.0011
78	5.600	8.400	5.604	8.403	0.0047	0.0026
79	5.600	11.200	5.606	11.202	0.0061	.0038
89	8.400	11.200	8.401	11.203	0.0011	0.0038
88	8.400	8.400	8.400	8.401	0.0002	0.0016
87	8.400	5.600	8.400	5.602	0.0002	0.0021
86	8.400	2.800	8.401	2.799	0.0015	-0.0003
85	8.400	0.000	8.409	0.000	0.0093	0.0003
84	8.400	-2.800	8.409	-2.800	0.0091	-0.0005
83	8.400	-5.600	8.410	-5.600	0.0104	-0.0001
82	8.400	-8.400	8.411	-8.403	0.0114	-0.0038
81	8.400	-11.200	8.411	-11.204	0.0117	-0.0041
91	11.200	-11.200	11.205	-11.203	0.0052	-0.0033
92	11.200	-8.400	11.204	-8.403	0.0041	-0.0035
93	11.200	-5.600	11.203	-5.599	0.0031	0.0004
94	11.200	-2.800	11.202	-2.800	0.0029	-0.0005
95	11.200	0.000	11.203	-0.000	0.0030	-0.0020
96	11.200	2.800	11.203	2.801	0.0032	0.0014
97	11.200	5.600	11.202	5.601	0.0025	0.0016
98	11.200	8.400	11.203	8.403	0.0032	0.0034
99	11.200	11.200	11.202	11.203	0.0029	0.0024
195	12.450	0.000	12.462	-0.003	0.0120	-0.0034
115	-12.450	0.000	-12.433	-0.005	0.0169	-0.0092
151	0.000	-12.450	0.006	-12.461	0.0060	-0.0112
159	0.000	12.450	0.003	12.449	0.0030	-0.0029

CALIBRATION OF RCA-RBV S19931** MARCH 2, 1975

**used in Camera 2, S/N 103

ORIGINAL PAGE IS
OF POOR QUALITY

REDUCTION OF RBV RESEAU MEASUREMENTS

CALIBRATION OF RCA-RBV S19944* MARCH 2, 1976

MEAN POSITIONS OF RESEAU MARKS (Millimeters)

POINT	NOMINAL POSITION		MEAN POSITION		DISPLACEMENTS FROM NOMINAL	
NO.	X	Y	X	Y	X	Y
11	-11.200	-11.200	-11.190	-11.210	0.0097	-0.0109
12	-11.200	-8.400	-11.188	-8.412	0.0112	-0.0122
13	-11.200	-5.600	-11.189	-5.609	0.0104	-0.0097
14	-11.200	-2.800	-11.190	-2.805	0.0096	-0.0052
15	-11.200	0.000	-11.192	-0.003	0.0070	-0.0039
16	-11.200	2.800	-11.194	2.802	0.0050	0.0025
17	-11.200	5.600	-11.195	5.601	0.0042	0.0010
18	-11.200	8.400	-11.197	8.403	0.0027	0.0036
19	-11.200	11.200	-11.199	11.206	0.0004	0.0061
29	-8.400	11.200	-8.399	11.208	0.0009	0.0084
28	-8.400	8.400	-8.397	8.404	0.0027	0.0043
27	-8.400	5.600	-8.394	5.601	0.0059	0.0016
26	-8.400	2.800	-8.394	2.799	0.0053	-0.0005
25	-8.400	0.000	-8.392	-0.001	0.0073	-0.0018
24	-8.400	-2.800	-8.391	-2.803	0.0094	-0.0035
23	-8.400	-5.600	-8.390	-5.605	0.0091	-0.0059
22	-8.400	-8.400	-8.389	-8.412	0.0104	-0.0126
21	-8.400	-11.200	-8.389	-11.209	0.0107	-0.0099
31	-5.600	-11.200	-5.587	-11.211	0.0125	-0.0111
32	-5.600	-8.400	-5.587	-8.410	0.0127	-0.0109
33	-5.600	-5.600	-5.588	-5.604	0.0112	-0.0043
34	-5.600	-2.800	-5.590	-2.803	0.0096	-0.0029
35	-5.600	0.000	-5.591	-0.001	0.0081	-0.0012
36	-5.600	2.800	-5.592	2.800	0.0063	0.0004
37	-5.600	5.600	-5.595	5.603	0.0048	0.0031
38	-5.600	8.400	-5.596	8.406	0.0039	0.0064
39	-5.600	11.200	-5.598	11.209	0.0017	0.0094
49	-2.800	11.200	-2.795	11.210	0.0049	0.0107
48	-2.800	8.400	-2.793	8.406	0.0060	0.0064
47	-2.800	5.600	-2.793	5.604	0.0069	0.0047
46	-2.800	2.800	-2.791	2.800	0.0088	0.0004
45	-2.800	0.000	-2.790	-0.001	0.0096	-0.0013
44	-2.800	-2.800	-2.787	-2.804	0.0121	-0.0040
43	-2.800	-5.600	-2.787	-5.604	0.0127	-0.0045
42	-2.800	-8.400	-2.786	-8.411	0.0139	-0.0112
41	-2.800	-11.200	-2.785	-11.208	0.0145	-0.0098
51	0.000	-11.200	0.004	-11.208	0.0042	-0.0083
52	0.000	-8.400	0.004	-8.410	0.0042	-0.0100
53	0.000	-5.600	0.002	-5.603	0.0024	-0.0032
54	0.000	-2.800	0.001	-2.803	0.0016	-0.0030
55	0.000	0.000	0.000	-0.000	0.0001	-0.0000
56	0.000	2.800	-0.002	2.802	-0.0021	0.0027
57	0.000	5.600	-0.001	5.604	-0.0016	0.0045
58	0.000	8.400	-0.002	8.406	-0.0029	0.0067
59	0.000	11.200	-0.005	11.210	-0.0052	0.0100
69	2.800	11.200	2.803	11.211	0.0035	0.0118
68	2.800	8.400	2.805	8.406	0.0058	0.0068
67	2.800	5.600	2.806	5.603	0.0069	0.0035

66	2.800	2.800	2.808	2.801	0.0083	0.0015
65	2.800	0.000	2.808	-0.000	0.0084	-0.0009
64	2.800	-2.800	2.810	-2.802	0.0104	-0.0027
63	2.800	-5.600	2.811	-5.605	0.0119	-0.0052
62	2.800	-8.400	2.812	-8.411	0.0125	-0.0112
61	2.800	-11.200	2.813	-11.211	0.0135	-0.0112
71	5.600	-11.200	5.613	-11.209	0.0133	-0.0097
72	5.600	-8.400	5.612	-8.411	0.0122	-0.0114
73	5.600	-5.600	5.610	-5.605	0.0109	-0.0054
74	5.600	-2.800	5.609	-2.803	0.0099	-0.0039
75	5.600	0.000	5.608	-0.000	0.0084	-0.0001
76	5.600	2.800	5.609	2.801	0.0091	0.0018
77	5.600	5.600	5.606	5.603	0.0063	0.0033
78	5.600	8.400	5.603	8.407	0.0038	0.0073
79	5.600	11.200	5.602	11.211	0.0025	0.0111
89	8.400	11.200	8.398	11.212	-0.0014	0.0126
88	8.400	8.400	8.400	8.407	0.0003	0.0076
87	8.400	5.600	8.402	5.604	0.0026	0.0043
86	8.400	2.800	8.405	2.801	0.0051	0.0018
85	8.400	0.000	8.414	0.000	0.0141	0.0000
84	8.400	-2.800	8.414	-2.803	0.0147	-0.0039
83	8.400	-5.600	8.415	-5.604	0.0150	-0.0046
82	8.400	-8.400	8.416	-8.410	0.0157	-0.0104
81	8.400	-11.200	8.417	-11.210	0.0175	-0.0104
91	11.200	-11.200	11.211	-11.211	0.0118	-0.0114
92	11.200	-8.400	11.210	-8.410	0.0107	-0.0108
93	11.200	-5.600	11.210	-5.605	0.0102	-0.0053
94	11.200	-2.800	11.208	-2.803	0.0087	-0.0031
95	11.200	0.000	11.207	-0.000	0.0076	-0.0001
96	11.200	2.800	11.206	2.803	0.0069	0.0031
97	11.200	5.600	11.204	5.604	0.0043	0.0046
98	11.200	8.400	11.204	8.408	0.0045	0.0089
99	11.200	11.200	11.201	11.211	0.0018	0.0119
105	12.450	0.000	12.463	-0.001	0.0131	-0.0015
115	-12.450	0.000	-12.440	-0.005	0.0093	-0.0050
151	0.000	-12.450	0.005	-12.462	0.0053	-0.0128
159	0.000	12.450	-0.005	12.456	-0.0058	0.0060

CALIBRATION OF RCA-RBV S19944* MARCH 2, 1976

*used in the Spare Camera, S/N 101

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ANALOG TELEMETRY CHARACTERISTICS

All telemetry characteristic plots are based on circuit analysis and are weighted in each case by actual results of individual circuit tests.

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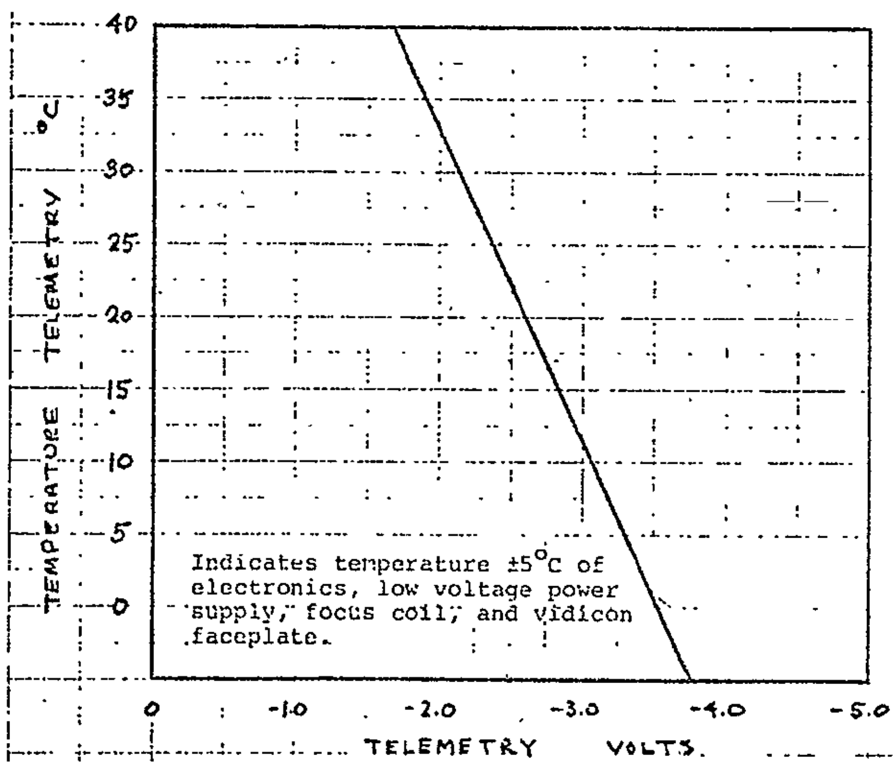

Figure IV-1. Temperature Telemetry

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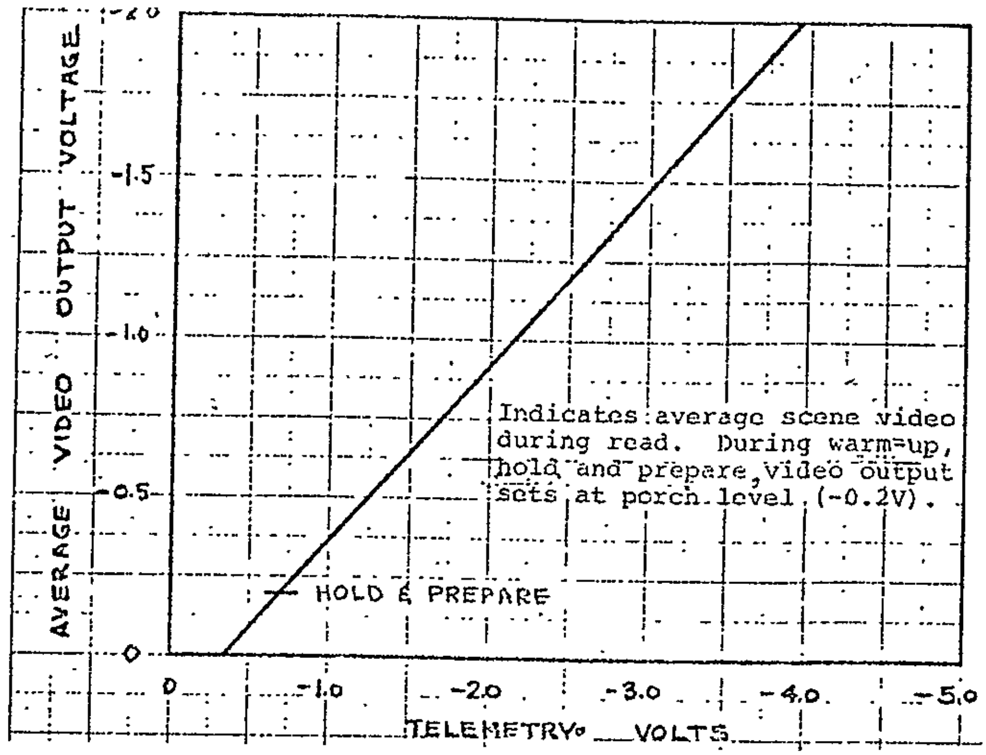

Figure IV-2. Video Output

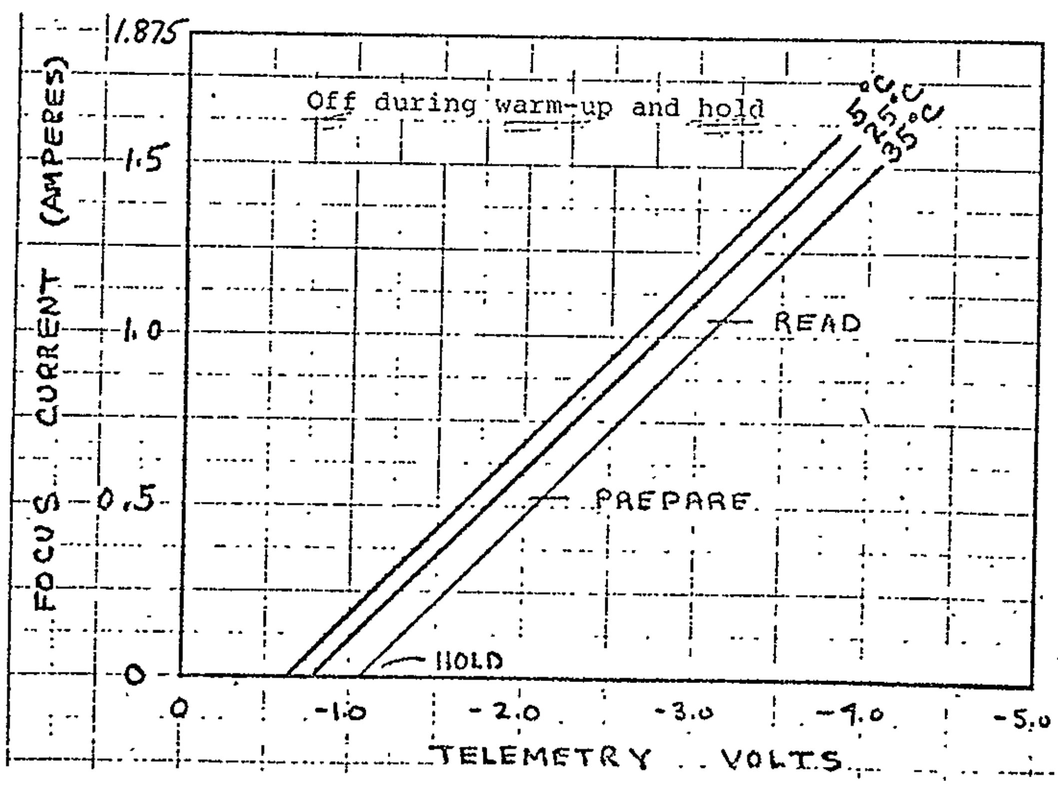

Figure IV-3. Focus Current

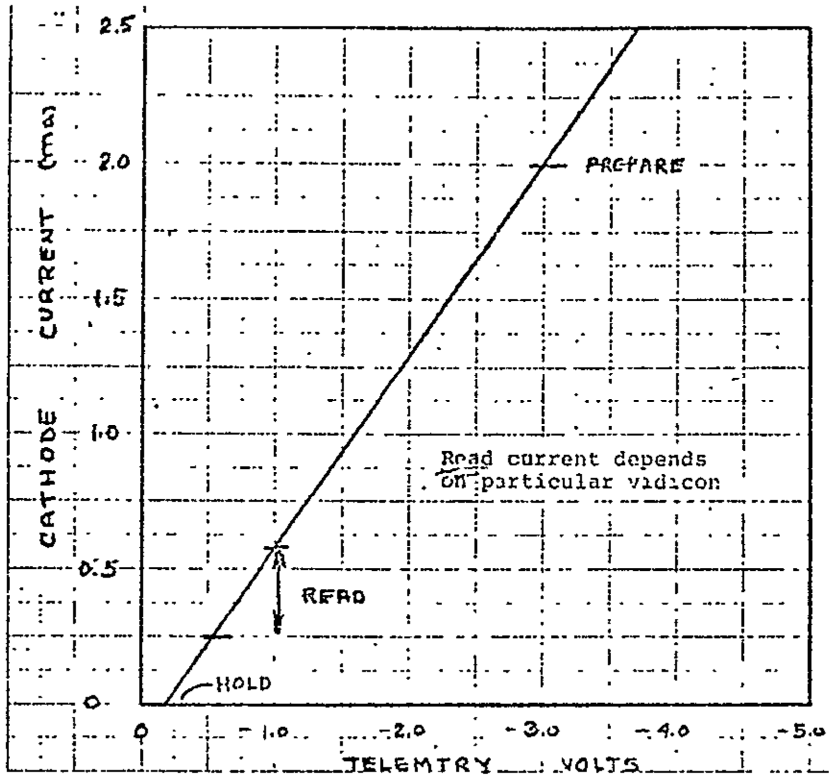

Figure IV-6. Vidicon Cathode Current

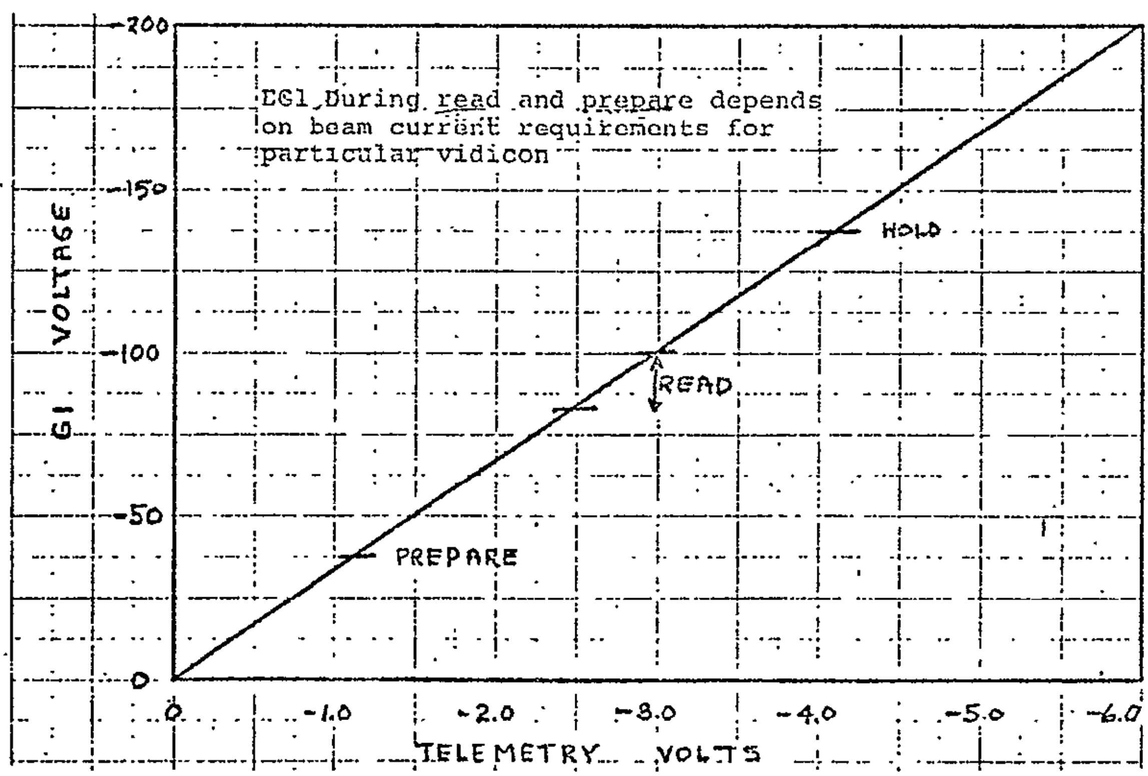

Figure IV-7. Vidicon G1 Voltage

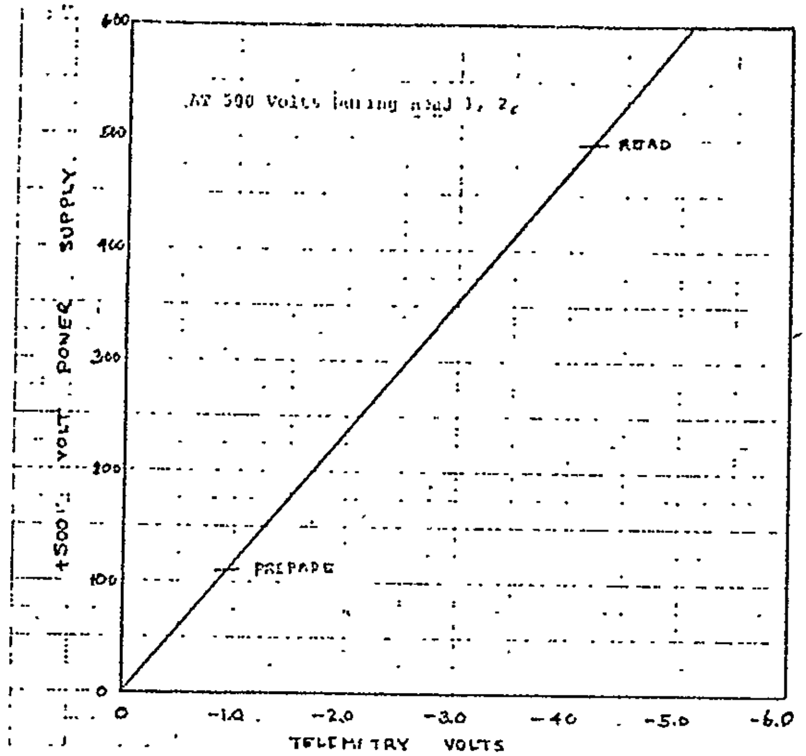

Figure IV-8. +500 Volts

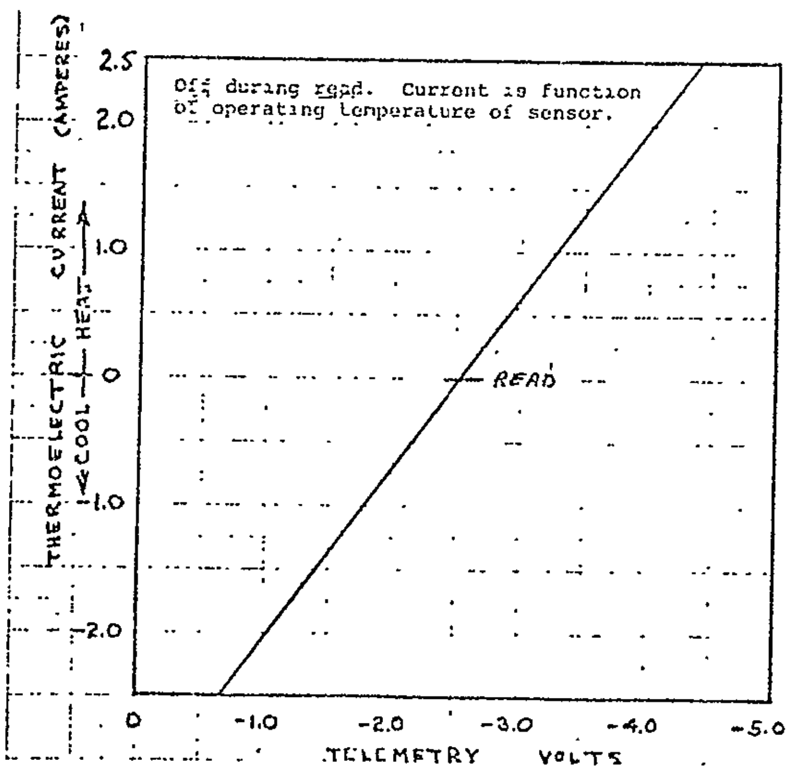

Figure IV-9. Thermoelectric Current

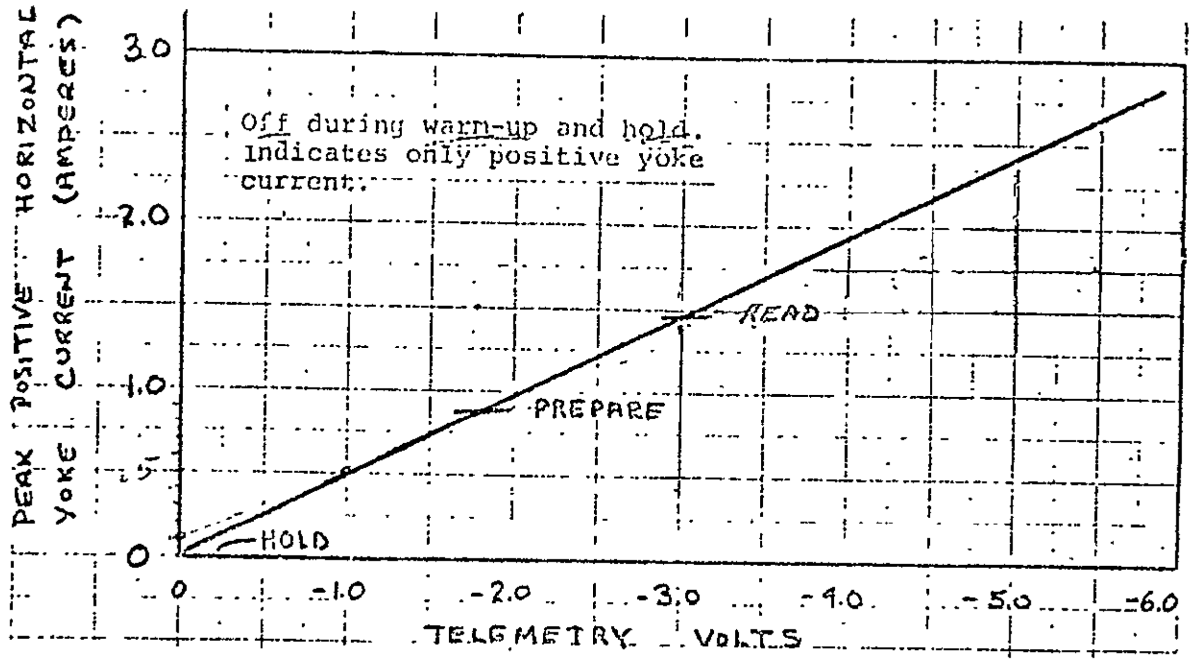

Figure IV-10. Horizontal Deflection

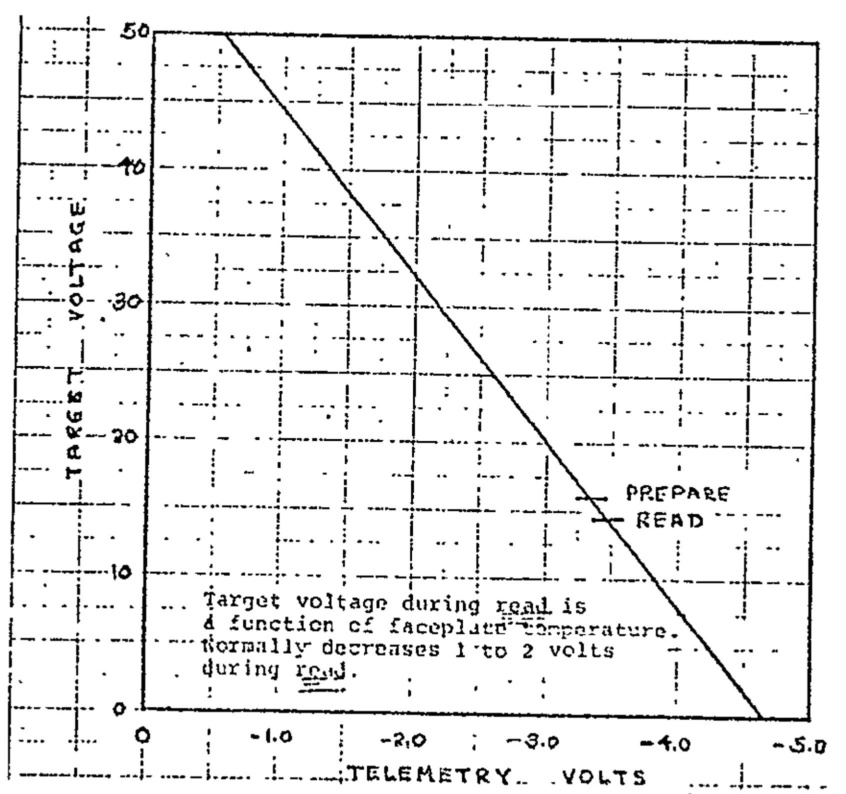

Figure IV-11. Vidicon Target Voltage

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